24GHz Transceiver: BGT24MTR11

Distance2Go-24GHz radar demo kit with BGT24MTR11 and XMC4200 32-bit ARM® CortexTM-M4 MCU for ranging, movement and presence detection

Board version 1 . 0

About this document

Scope and purpose

This application note describes the key features of Infineon's Distance2Go module equipped with the 24GHz transceiver chipset BGT24MTR11 and the 32-bit ARM® CortexTM-M4 based XMC4200 Microcontroller and helps to quickly get started with the demo board.

1. The application note describes the hardware configuration and specifications of the sensor module in detail
2. The document provides a guide to configure the hardware and implement simple radar applications with the firmware/software developed.

Intended audience

This document serves as a primer for users who want to get started with hardware design for distance measurement sensors using Frequency Modulated Continuous Wave (FMCW) radar technique at 24GHz.

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1 Introduction

The Distance2Go is a demonstration platform as well as a starter kit for Infineon's Silicon-Germanium (SiGe) based 24 GHz radar chipset. The module provides a complete radar system evaluation platform including demonstration software and a highly interactive graphical user interface (GUI). The radar system consists of the following Infineon components

- BGT24MTR11 - Highly integrated 24 GHz transceiver IC with 1 Transmitter (TX) and 1 Receiver (RX)
- XMC4200 - 32-bit ARM® CortexTM-M4 based microcontroller XMC4200 for signal processing
- BAS3010 - Reverse current protection diode
- ESD8V0L2B - Diode for protection of the USB port against electrostatic discharge
- IRLHS2242 - 20V Single P-Channel HEXFET Power MOSFET for duty cycle operation
- XMC4200 Onboard-Debugger – Licensed firmware for Serial Wire Debug (SWD) and UART to USB communication

The radar module is powered over USB through multiple low noise voltage regulators. The platform is suitable to implement radar applications like motion detection and direction of movement analysis using Continuous-Wave (CW/Doppler) radar and distance measurement using Frequency Modulated Continuous-Wave (FMCW) technique. An onboard low noise fractional-N Phase Locked Loop (PLL) performs the frequency control and FMCW ramp generation. Multi-stage low noise baseband amplification stages are used for enhanced target detection. An onboard breakable debugger with a licensed firmware from SEGGER; allows easy debugging over the USB. This eliminates the need for an external debugging tool. The module features integrated microstrip patch antennas on the PCB with design data, thereby eliminating antenna design complexity at the user end.

This application note describes the key features and hardware configuration of the Distance2Go module in detail. The Distance2Go is designed to evaluate the capabilities of the BGT24MTR11 chipset with the XMC4200 microcontroller by utilizing Infineon's powerful, free of charge tool chain DAVETM for microcontroller programming.

Note: This board does not serve as a reference design. The hardware and software provided with this board are for demonstration purpose only.

2 Overview

The Distance2Go module contains a Radar main board and a breakable debugger board. The radar main board contains four important sections: an RF Part, an analog amplifier part, frequency control part and a digital part. The RF part consists of the Infineon 24GHz radar MMIC - BGT24MTR11 and includes microstrip patch antennas for the TX and RX section. The digital part consists of XMC4200, 32-bit ARM® CortexTM-M4 microcontroller from Infineon to sample and process the analog data from the radar front-end and also to configure the BGT24MTR11 chip via an SPI Interface. The analog amplifiers provide the interface between RF part and digital part of the board. The frequency control part contains a low noise fractional-N PLL. The main use case of this board is to demonstrate the features the BGT24MTR11 RF frontend chip and to give the user a working piece of hardware that makes it possible to quickly gather sampled radar data that can be used to develop radar signal processing algorithms on a PC or implement target detection algorithms directly on the microcontroller using DAVE. A highly interactive Graphical User Interface is available to visualize the real-time raw IF quadrature output signals, FFT spectrum and observe the targets' distance and velocity information.

2.1 Key features

The Distance2Go DEMO board has the following features

- BGT24MTR11 24GHz RF frontend chip with 1 TX and 1 RX and the following features
    - Low noise figure NFssb: 12 dB
    - High conversion gain: 26 dB
    - High 1dB input compression point: -12 dBm
    - Switchable Prescaler with 1.5 GHz and 23 kHz output
    - On chip power and temperature sensors
- XMC4200 Cortex-M4 microcontroller for sampling and signal processing of the analog signals with the following features
    - 80MHz CPU Frequency, 256kB flash and 40kB RAM size
    - Two Capture/Compare Units 4 (CCU4) for use as general purpose timers
    - Two 12-bit Analog-Digital Converters (VADC), 8 channels each, with input out-of-range comparators and a 12-bit Digital-Analog Converter (DAC) with 2 channels
    - USB 2.0 device, with integrated PHY, Controller Area Network interface (MultiCAN), Full-CAN/Basic-CAN with two nodes, 64 message objects (MO), data rate up to 1 MBit/s
    - Four Universal Serial Interface Channels (USIC), providing four serial channels, usable as UART, double-SPI, quad-SPIIIC, IIS and LIN interfaces
- Onboard breakable debugger with UART communication
- Onboard Low Noise Fractional-N PLL with Chirp generation
- One standby LED, one user configurable on board LED and one user configurable GPIO pin
- Dual analog amplifier stage for each RX channel with user configurable gain settings
- Transparent connectors to probe the BGT24MTR11 IF outputs and also test several pins
- Microstrip Patch Antennas with 12dBi Gain and 20°x42° Field of View (FOV)

- Onboard PMOS Switch for Duty-Cycle operation of BGT24MTR11
- Power Supply
    - Via Micro-USB connector
    - Via external power supply (5V Maximum)

2.2 Block diagram

Figure 1 shows the block diagram of the demo board. The board is split into a radar unit and a breakable debugger unit for programming. The radar unit consists of the highly–integrated 24 GHz transceiver IC BGT24MTR11 with 1 TX and 1 RX. The MMIC features an integrated voltage controlled oscillator (VCO), power amplifier (PA), integrated temperature and power sensors, Prescalers and IQ receivers.

The board has integrated microstrip patch antennas and a Wilkinson combiner is used to combine the differential transmitter output power from the radar IC before feeding it to the antennas. Each receiver channel is connected to dual analog amplifier stage at its IF outputs. A 32-bit ARM® CortexTM-M4 XMC4200 microcontroller is used to sample and process the analog downconverted signals from the baseband amplifiers using the integrated 12-bit Analog-Digital Converters (ADC), and also control the radar chip via the SPI interface. The output power of the radar chip and the gain of its receive section can be controlled via the SPI settings. There are also SPI commands to readout the different sensor outputs. A low noise fractional-N phase locked loop (PLL) IC is used to perform the frequency control and ramp generation. The output of the /16 integrated Prescaler on the radar IC is connected to the PLL RF input pins and the output voltage from the PLL charge pump is connected via a loop filter to the tuning ports of the BGT24MTR11 thereby forming a closed loop system. This procedure is used to lock the transmitted signal of the module to an output frequency inside the ISM band. The /65536 integrated Prescaler produces a low frequency output signal (around 23 kHz) which is connected to a compare and capture unit (CCU4) of the XMC4200 for monitoring purpose.

The module is powered over the micro-USB plug, and several low noise voltage regulators are used to provide a regulated power supply to the different building blocks .The BGT24MTR11 MMIC is supplied over a PMOS, which enables to operate the sensor in a duty-cyle mode. The Distance2Go features a breakable on-board debugger which comes preloaded with a licensed firmware for debugging and communicating with the main radar MCU via the UART pins. Pin headers on the PCB allow interfacing the sensor module with an external processor.

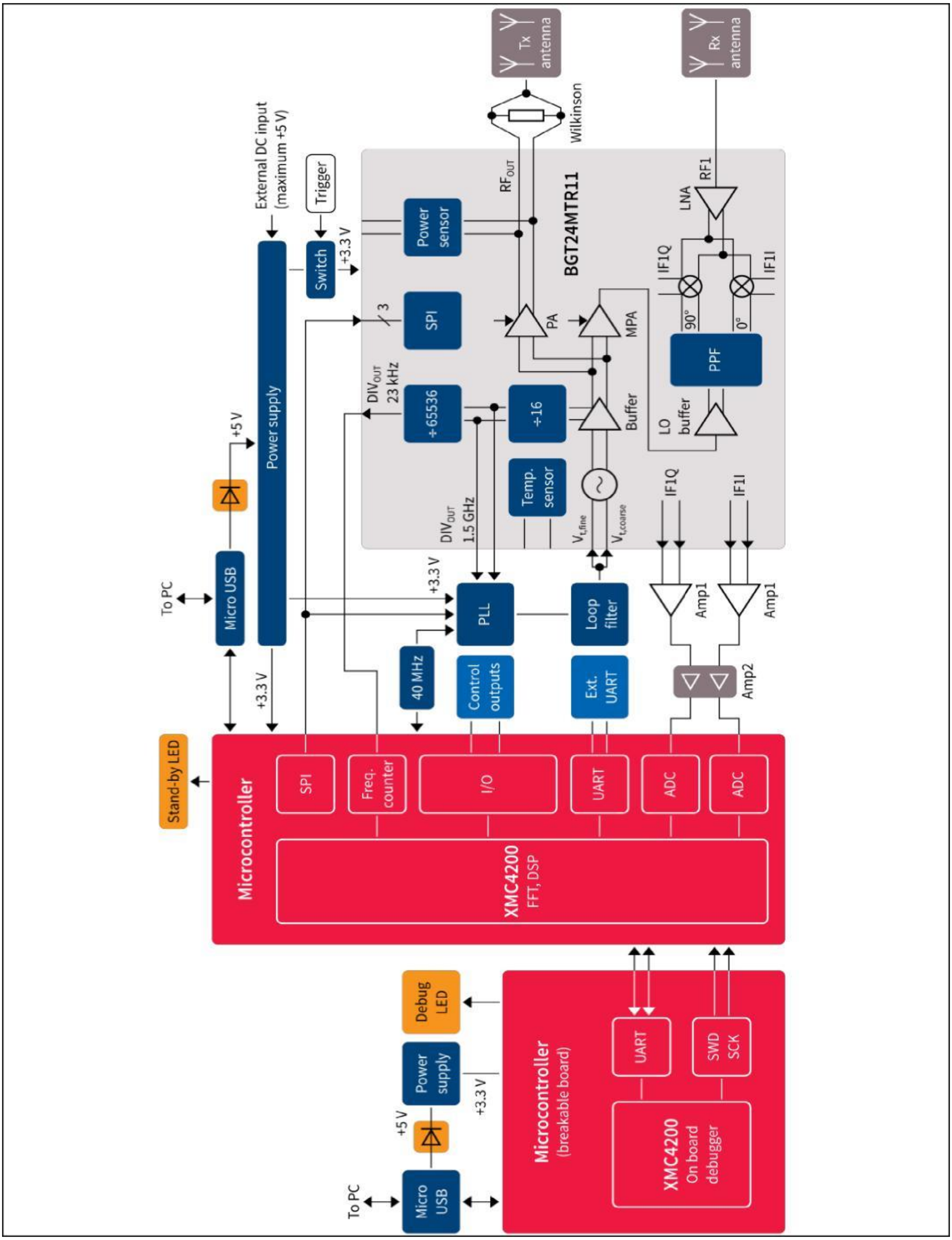


Figure 1 Block Diagram – Distance2Go Module

3 Distance2Go module specifications

Table 1 gives the specification of the Distance2Go module

Table 1 Distance2Go Module Performance Specifications(1)

Parameter	Unit	Min.	Typ.	Max.	Comments
Supply Voltage	V		5	5.5	
Supply Current	mA		400		

Transmitter Characteristics

Transmitter Frequency	GHz	24.0		24.25	
EIRP (Effective Isotropic Radiated Power)	dBm		+ 18		**Conditions :** BGT Pout : +11dBm Loss (TXOUT to Antenna Input = 2dB) Simulated Ant Gain= +12 dBi
VCO Fine Pin Tuning Sensitivity	MHz/V			1500	
VCO Coarse Pin Tuning Sensitivity	MHz/V			3000	Vcoarse = Vfine on the module
VCO Temperature Drift	MHz/K	-10	-6	0	Min. @ T = -40°c
VCO Pushing	MHz/V	-350	60	350	Absolute values
TX Output Power Adjustable Range	dB	3	9		Adjustable via SPI Settings
System Phase Noise with PLL	dBc/Hz		-89		@100 kHz offset, Vcoarse = Vfine. Measured in CW mode
External Oscillator Frequency	MHz		40		

Receiver Characteristics

Receiver Frequency	GHz	24.0		24.25	
Conversion Gain – RF Front End	dB		26		$R_{LOAD,IF}$ >10Kohm
Single Sideband Noise Figure (NFssb) – RF FrontEnd	dB		12		Single sideband at IF Frequency= 100 kHz
RF Frontend LNA Gain Reduction	dB	3	5	8	Configurable via SPI Settings
Quadrature Amplitude Imbalance	dB	-1		+1	
Quadrature Phase Imbalance	deg	-10		+10	
IF Conversion Gain - Low Gain Mode – (Stage 1)	dB		34		Default Setting of the Sensor Module when delivered
-3dB Bandwidth – Low Gain Mode – Stage 1	kHz		2 kHz – 200 kHz		Default Setting of the Sensor Module when delivered
IF Conversion Gain - High Gain Mode – (Stage 1 + Stage 2)	dB		64		Can be selected by reconfiguring the ADC pins in DAVE Project

Table 1 Distance2Go Module Performance Specifications[1]

Parameter	Unit	Min.	Typ.	Max.	Comments
-3dB Bandwidth – High Gain Mode – (Stage 1 + Stage 2)	kHz		14 kHz – 120 kHz		Can be selected by reconfiguring the ADC pins in DAVE Project

Antenna Characteristics (Simulated)

Antenna Type			2x4		
Horizontal - 3dB beamwidth	deg		42°		
Elevation - 3dB beamwidth	deg		20°		
Horizontal Sidelobe level suppression	dB		-13		
Vertical Sidelobe level suppression	dB		-13		

System Performance

Minimum Distance	50 cms	Radar Cross Section (RCS) = 1m^2 and 10m^2
Maximum Distance	15m 26m	RCS = 1m^2 RCS = 10m^2
Measurement Accuracy (For values beyond 50cms)	±30cm ±20cm	RCS =1m^2 RCS = 10m^2

1) The above specs are indicatory values based on typical datasheet parameters of BGT24MTR11 and simulation of several other parameters (Antenna characteristics and Baseband Section) and can vary significantly from module to module. The numbers above are not guaranteed indicators for module performance for all conditions of operations.

4 Distance2Go hardware description

This section gives a detailed overview of the hardware platform and how it can be used.

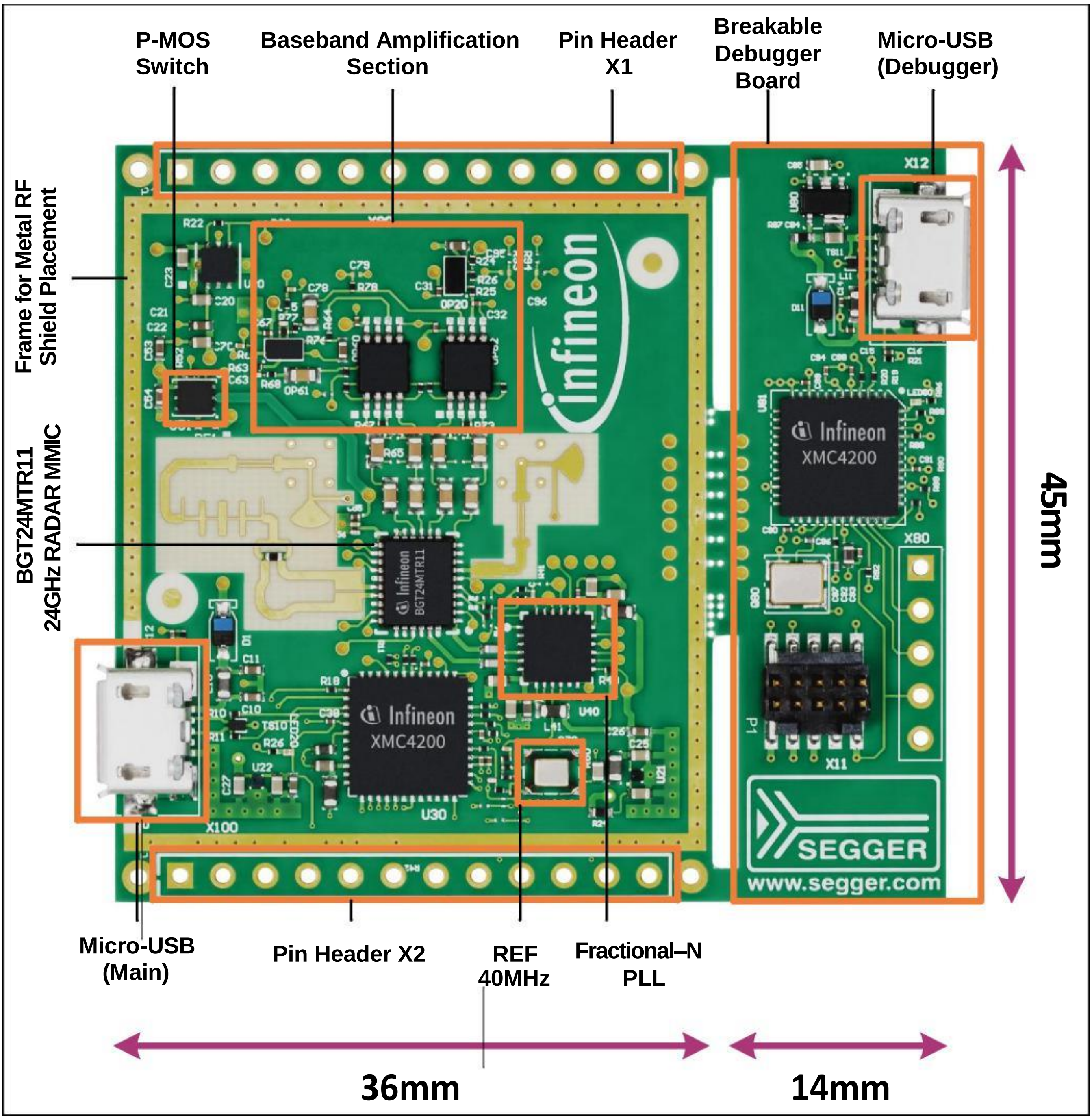


Figure 2 Distance2Go Demo Board - Location of Different Building Blocks

Figure 2 gives an overview of the components on the demo board. Sections below describe the functionality of each part in detail.

4.1 Power supply

Figure 3 shows the power supply concept used on the module.The board is powered over Micro USB connector when used with a PC. There is also the provision to provide the power supply via an external DC input pin (5V maximum). The USB plugs on the main board as well as the breakable debugger board can be used to supply the module.

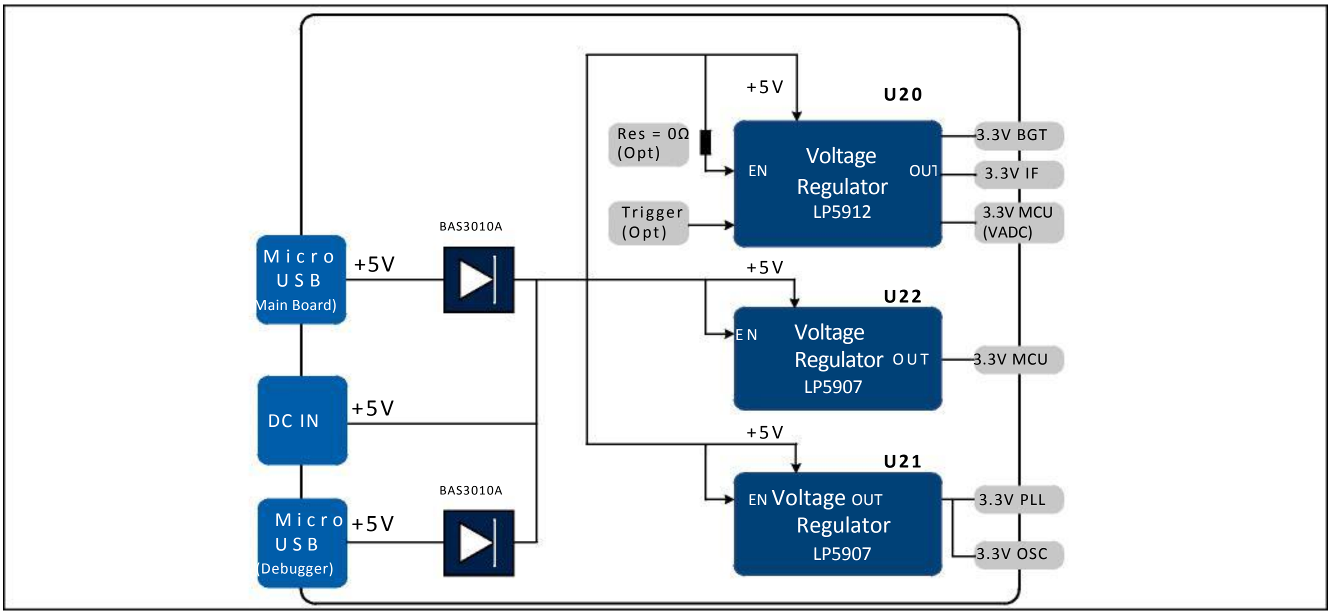


Figure 3 Block Diagram – Power Supply Concept

The power supply via the USB or external input is provided to three different voltage regulators. The 24GHz transceiver IC is powered by a low noise voltage regulator U20 capable to drive upto 500mA. U20 has an enable pin which is connected to the input voltage pin via a 0Ω resistor R22 as shown in Figure 4. The module also provides an option to trigger the enable pin via the P1.4 of the MCU. In this case the resistor R22 must be removed and 0Ω resistor must be soldered in place of R23. Regulator U20 is also used to supply the analog domain of the XMC4200 MCU and the baseband IF amplifiers. A second low noise voltage regulator U22 is used to supply the digital microcontroller unit of the board. A third low noise regulator U21 is used to power up the PLL and the 40MHz reference oscillator. The enable pins of U21 and U22 are hardwired to their input voltage pins on the PCB and are not available to the users. Regulators U21 and U22 can drive upto 250mA each. Depending on the settings, the entire PCB can draw typically upto 400mA current.

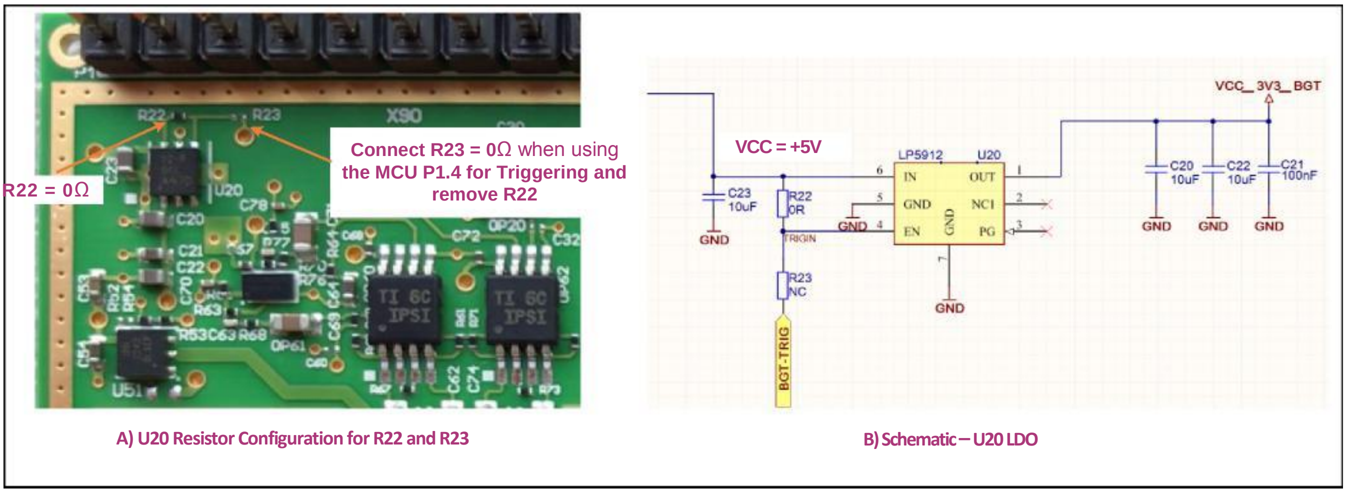


Figure 4 Configuration of U20 Regulator for Low Power Operation

4.2 RF frontend

Figure 5 shows the top view of the RF frontend. The RF Frontend can be shielded with a cover and absorber material to get the best RF performance. The metal frame around the PCB as shown in Figure 2 can be used to glue such a shield on top of the RF frontend. Following paragraph describes the various sections of the RF frontend in detail.

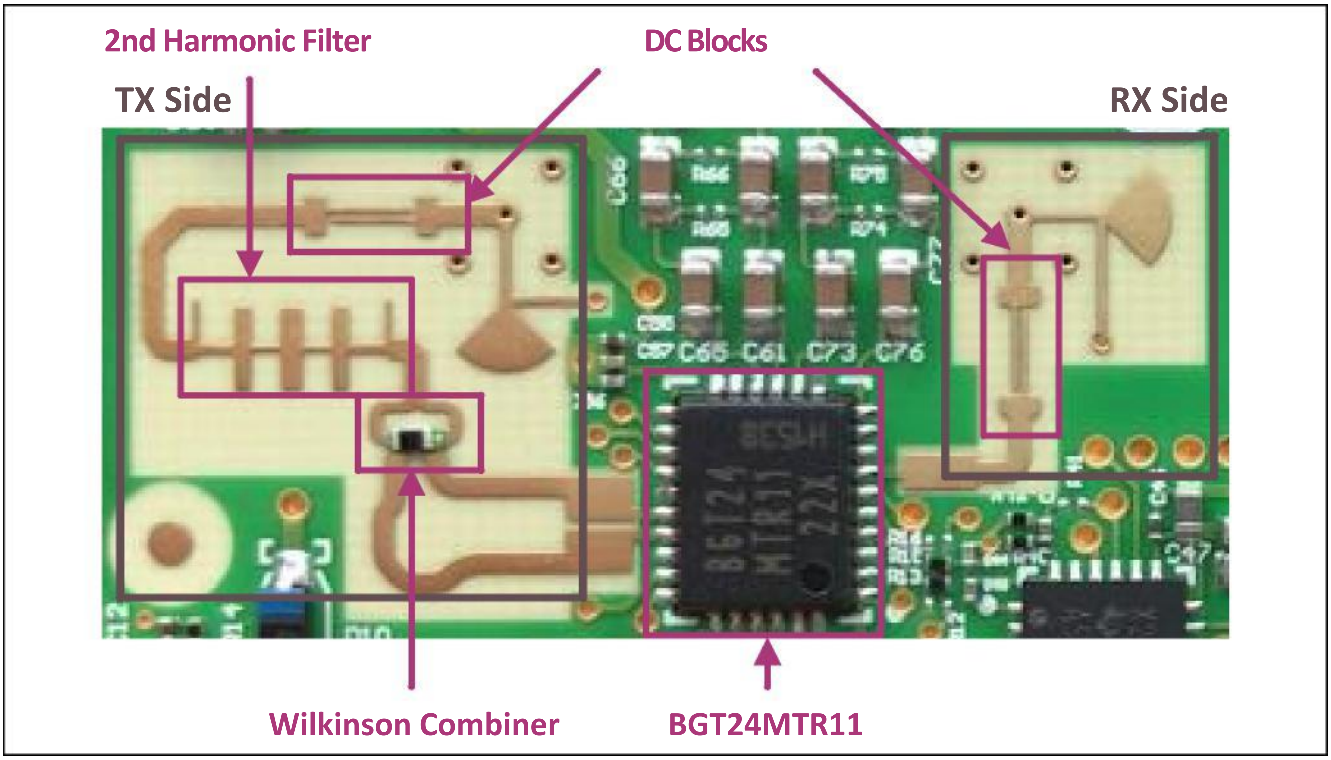


Figure 5 RF Frontend Overview (Top)

4.2.1 Board stackup

It is necessary to use a defined board layer stack-up for a proper functioning of the RF-part. All the microstrip RF parts have to be calculated according to the used stackup. The cross-sectional view of the PCB is shown in Figure 6. The module uses 6-layer stack up with a symmetrical RO-4350B core. The matching structures for the transmitter and receiver part are designed based on this stack-up.

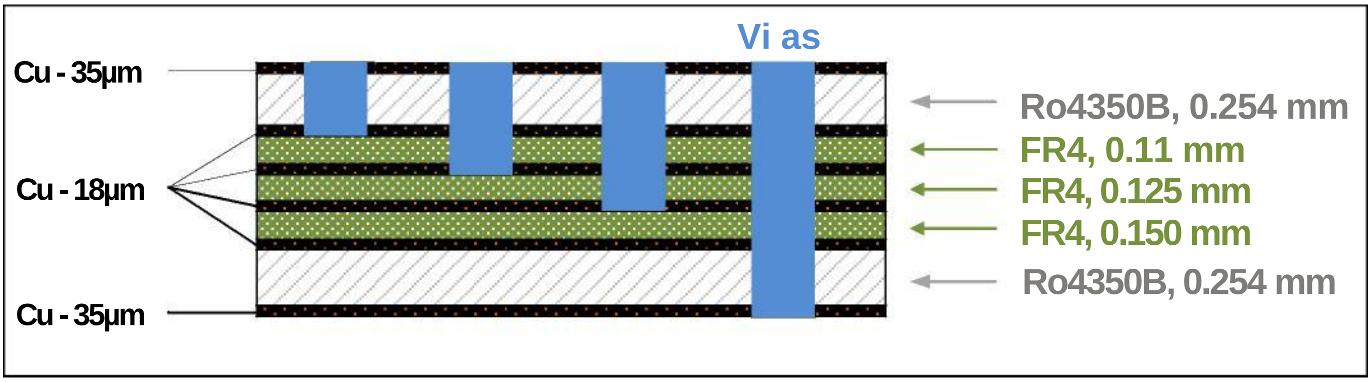


Figure 6 PCB Cross-Section

The most important part for the RF microstrip components is the top and bottom RO-4350B, 0.254mm thick core. On the top layer (layer 1) are the microstrip structures and the layer 2 is the RF ground for the microstrip components used on the top layer. Layer 3 and layer 4 are used for routing various signals. On the bottom layer (layer 6) are the microstrip patch antennas and layer 5 is the RF ground for the microstrip patch antennas. The substrate thickness for the other layers have been chosen taking into account the blind-via diameters used on the pcb and this can vary depending upon the pcb manufacturing technology (aspect ratio). From simulations it was observed that such minor variation of the thickness of these FR4 substrates have very low impact on the RF performance.

4.2.2 BGT24MTR11 – 24GHz transceiver MMIC

The heart of the sensor module is the highly integrated BGT24MTR11 24GHz transceiver IC. Figure 7 shows the detailed block diagram of the MMIC.

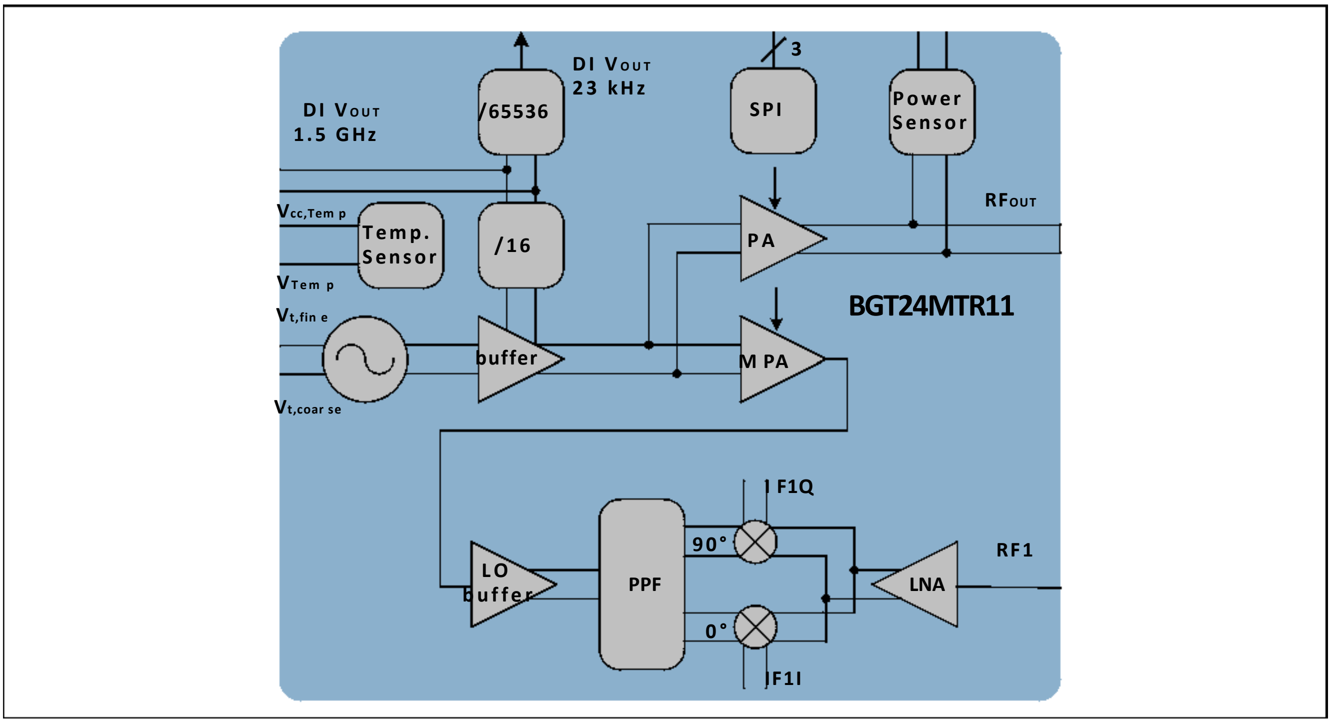
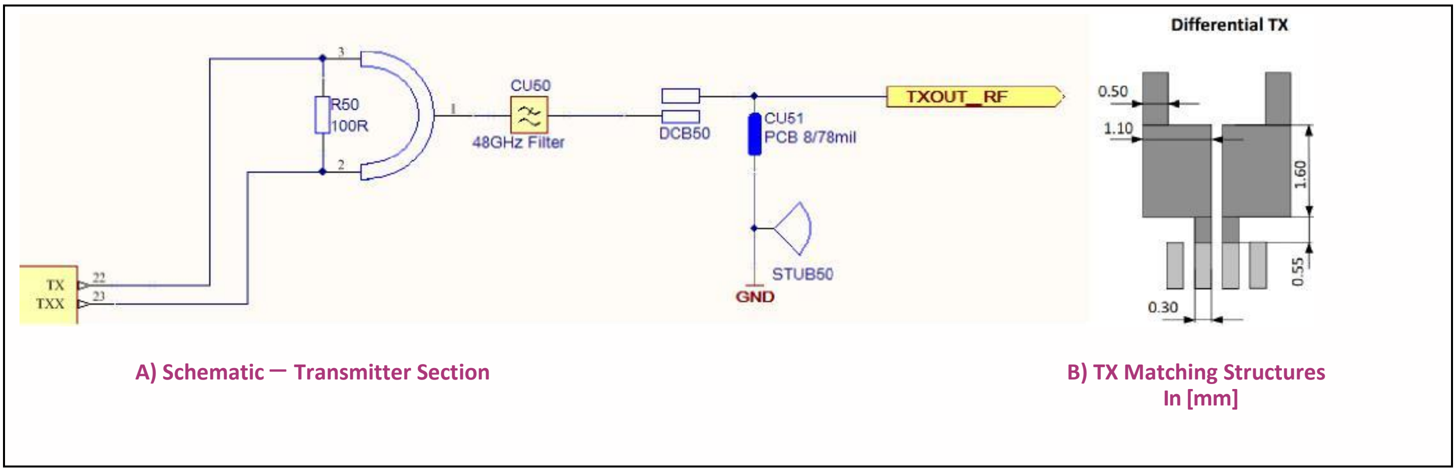


Figure 7 Block Diagram – BGT24MTR11

The MMIC features a very high level of integration which includes, a voltage controlled oscillator (VCO) with prescaler outputs for frequency control, transmitter chain including amplifiers for both transmitter (TX) and local oscillator (LO) outputs, as well as the complete receiver section including low noise amplifier (LNA) and mixer. The VCO is a free running, fundamental oscillator. It can be controlled by two tuning inputs, one for coarse preadjustment and one for fine-tuning. There are two prescalers available in the VCO section of the chip. The first prescaler has an output frequency of 1.5 GHz and can be used to feed an RF-PLL for frequency control. The second prescaler has a 23 kHz square-wave output that may be used by a microcontroller-based software loop. The TX section consists of a power amplifier with a differential output. Its typical output power is +11 dBm and can be reduced in eight steps down to 2 dBm. A part of the TX signal is used as the LO signal for the on-chip mixer. The receiver section has a single-sideband noise figure of 12 dB and a voltage conversion gain of 26 dB. The gain of the LNA can be reduced by a typical gain-step of 5 dB. The built-in quadrature downconversion mixer translates the RF signal directly to zero-IF. Additionally, the chip features power sensors both on TX-outputs and LO-outputs, as well as a temperature sensor that supports the implementation of a software based loop to control the VCO. The settings of the different internal building blocks can be controlled via an SPI interface. When fully turned ON, the chip consumes approximately 500mW from a 3.3V power supply.

4.2.3 Module transmitter section

The transmitter output of BGT24MTR11 is differential. The differential outputs are first connected over matching structures followed by a Wilkinson power combiner. The matching structures compensates for the bondwire inductance and other parasitic effects due to the VQFN package. Figure 8 shows the schematic of the transmitter section and the dimensions of the matching structures used at the TX outputs. The Wilkinson power combiner combines the differential signals into single-ended ones. Following the power combiner a second harmonic microstrip filter is used to attenuate the harmonics around 48GHz. The harmonic filter provides an attenuation >20 dB for frequencies around 48GHz and shows a simulated loss of approximately 0.5 dB. The filter path then goes over a DC block and a feedthrough via to the other side of the PCB to the antennas. The simulated loss for the entire RF section connecting the TX output from the MMIC to the antennas on the other side of the board including the vias was approximately 2 dB. There are DC shorts before the feedthrough vias

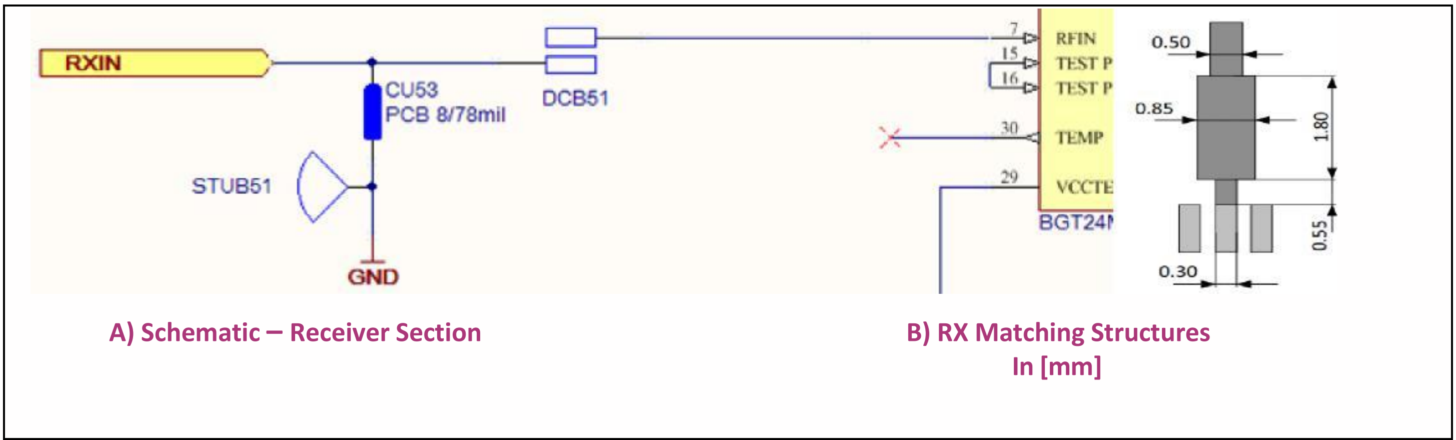


for enhanced ESD protection.

Figure 8 Transmitter Section Schematic and Matching Structure Dimensions

4.2.4 Module receiver section

The receiver input of the BGT24MTR11 is single-ended. The RX input is connected over a matching structure, a DC block and a feedthrough via to the antennas on the other side of the board. Figure 9 shows the schematic of the receiver section and the dimensions of the matching structures used at the RX input. The simulated loss for the entire RF section connecting the RX input at the MMIC to the antennas on the other side of the board



including the vias was approximately 1 dB. There are DC shorts before the feedthrough vias for enhanced ESD protection.

Figure 9 Receiver Section Schematic and Matching Structure Dimensions

4.2.5 Antennas

Distance2Go features 2x4 microstrip patch antennas for both transmit and receive sections. The antennas have a simulated gain of approximately 12dBi and an opening angle of 20°x42°. The simulation includes via losses. Figure 10 shows the simulated 2D and 3D radiation pattern.

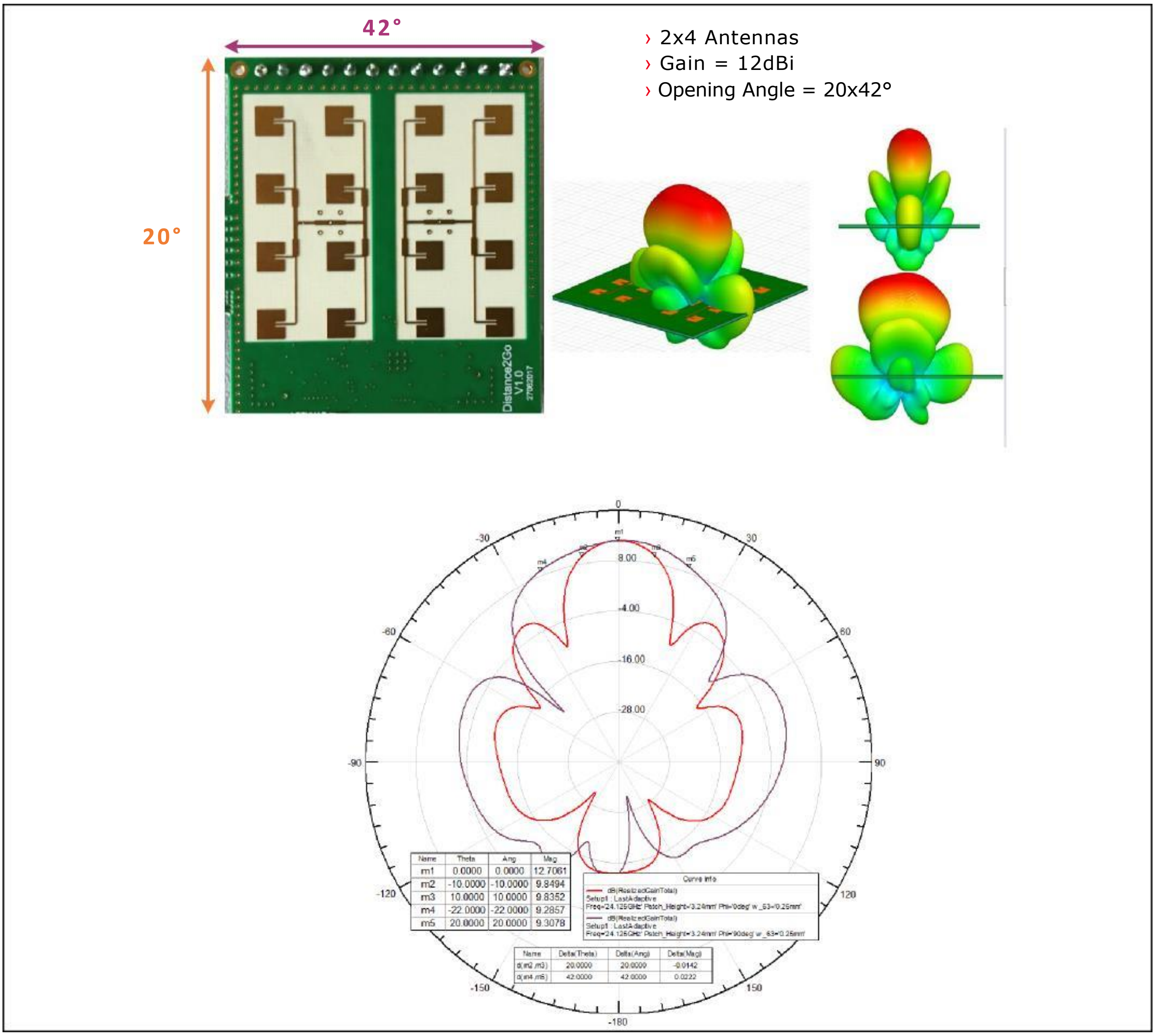


Figure 10 2D & 3D Radiation Pattern for Microstrip-Patch Antennas (Simulated)

Based on PCB material tolerances, the antenna performance can vary significantly from one production lot to another. Prior experience also shows that samples within the same production lot can also show significant variation in EIRP. This will inturn affect the EIRP of the sensor module. The EIRP variation of the modules also depends on the minimum, typical and maximum output power specifications of the BGT24MTR11 transmitter. One very important point about the antenna specifications is the definition of its opening angle which is defined as the 3dB -Half Power Beamwidth (HPBW). It must be noted that the values of 20°x42° does not imply that there is no transmission or reception beyond these angles. They only mean that the gain of the antenna beyond these angles is 3dB lower than the maximum gain at 0°. In practical cases, a target with large RCS can easily compensate for this reduced gain and get detected by the radar. Also depending on the distance of the target from the radar, even weaker targets outside the opening angle can be detected by the radar. Therefore a careful judgement has to be made regarding the radar detection zone by taking into account both distance of target from radar and also the target RCS.

4.3 Prescaler output and Phase Locked Loop (PLL) section

BGT24MTR11 has two prescaler outputs: Q1/Q1n and Q2. Q1/Q1n represents the VCO output divided by a factor 16 and is differential. Q2 represents the VCO output divided by a factor of 1 million (1048576 exactly). On the Distance2Go the Q1/Q1n output is connected to the RF input terminals of a low noise fractional-N PLL LMX2491 with integrated Ramp/Chirp generation functionality. The Prescaler output from the MMIC is DC-coupled. This is connected to the PLL via capacitors C51 and C52. The VCO can be controlled by DC inputs on two different pins: VCOARSE (Pin 5) and VFINE (Pin 4) of the BGT24MTR11. The VCOARSE and VFINE pins are tied together and connected to the PLLs charge pump output voltage via a loop filter circuit. The loop filter has been optimized for a wide bandwidth and low phase noise operation. A 40MHz reference oscillator is used as the clock source for the PLL. Table 2 lists the loop filter components with their values.

Table 2 PLL Loop Filter Components and Values

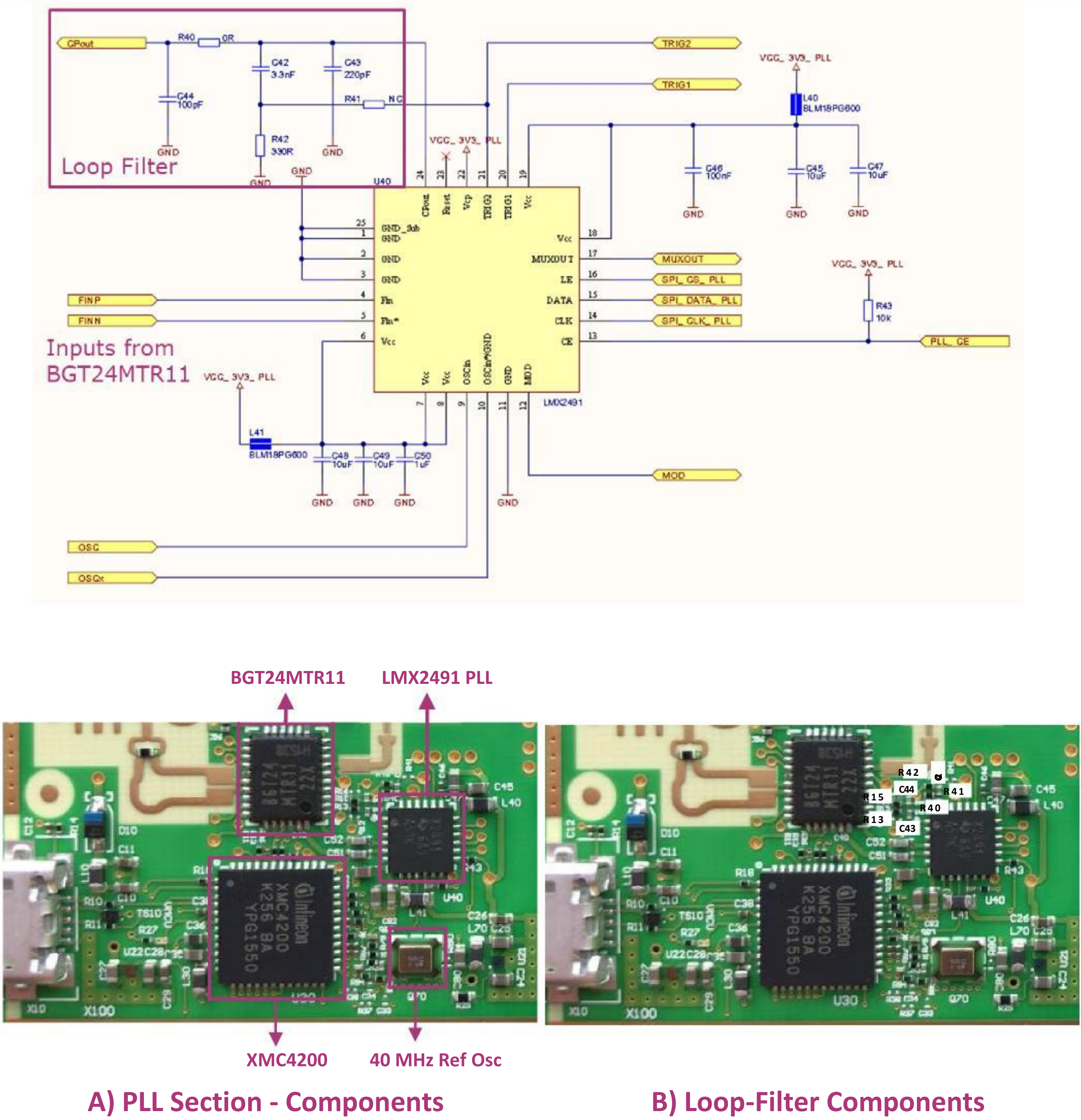
Component	Value
C42	3.3 nF
C43	220 pF
C44	100 pF
R40	0 ohms
R42	330 ohms

With the above values and appropriate PLL register and charge pump current settings, a phase noise better than -88dBc/Hz is achieved for offset frequencies between 10 kHz and 1 MHz. For phase noise measurements the module was set into continuous-wave mode (Doppler) operation. The loop filter provides a wide bandwidth (>250 kHz). The current firmware version provided with the module is tested with sawtooth ramps from 500 µs to 3ms. In principle, use of other ramp types (eg. Triangular) and other ramp durations should also be possible. However this is not tested using the provided firmware and may require reconsidering other system timing settings (eg. Duty-cycling, waiting times etc.). The module can be configured for both Doppler and FMCW operation by choosing the appropriate PLL settings. For the optimized PLL settings, refer to the DAVE project delivered with the hardware. The PLL consumes approximately 55mA from 3.3V power supply when fully ON. To reduce the power consumption of the module, the PLL can be enabled/disabled via the Chip Enable (CE) pin or SPI. Apart from the SPI pins, Table 3 lists the other PLL pins accessible on the module via the MCU for various configuration setting.

Table 3 PLL Pin Description

Pin Number - PLL	Description	Functionality	MCU Pin Connection
Pin 12	MOD	Multiplexed I/O Pins for Ramp Triggers, FSK/PSK Modulation, FastLock, and Diagnostics	P1.1
Pin 13	CE	Chip Enable	P0.6
Pin 17	MUXOUT	Multiplexed I/O Pins for Ramp Triggers, FSK/PSK Modulation, FastLock, and Diagnostics	P2.1
Pin 20	TRIG 1	Multiplexed I/O Pins for Ramp Triggers, FSK/PSK Modulation, FastLock, and Diagnostics	P1.2
Pin 21	TRIG 2	Multiplexed I/O Pins for Ramp Triggers, FSK/PSK Modulation, FastLock, and Diagnostics	P1.3

The Q2 Prescaler output from the BGT24MTR11 is around 23 kHz and this is fed into a Compare-Capture Unit (CCU4) of the XMC4200 MCU. This can be used to keep the VCO inside the ISM band by controlling the tuning voltage pins via the MCUs Digital to Analog Converter (DAC). This procedure would eliminate the need for hardware PLL but requires complex ramp generating techniques and signal processing algorithms for proper target detection. The Distance2Go PCB is designed to implement this functionality if one desires to do so. However Infineon currently does not provide any firmware, supporting such software based ramp generation for distance measurement. When using the Q2 output, it is very important to keep the Q1/Q1n output terminated to obtain a proper Q2 signal at the microcontroller timer input. It is recommended to keep the Q2 divider OFF



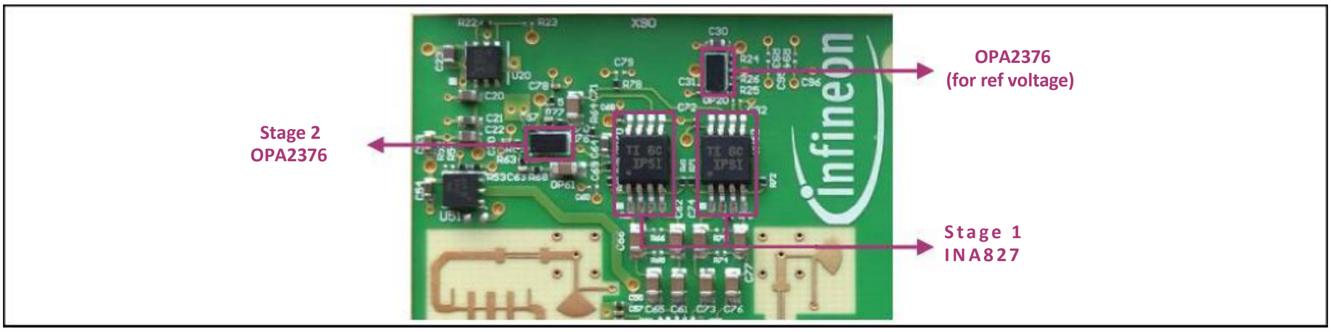
during signal processing to prevent unwanted spurs.

Figure 11 PLL Section Overview with Loop Filter Components

4.4 Analog baseband section

The BGT24MTR11 provides both inphase and quadrature phase Intermediate frequency (IF) signals from its receiver. The inphase and quadrature phase signals are differential in nature, thus making available four different IF output signals (IFIP, IFIN, IFQP and IFQN). Depending on the target in front of the radar antennas, the analog output signal from the BGT24MTR11 chipset can be very low in amplitude (µV to mV range). To process these low amplitude signals it is necessary to amplify the IF signals that comes out of the RF frontend with analog amplifiers.

Each IF path comprises two stages of low noise amplification. The first stage consists of two low noise instrumentation amplifiers (OP60 and OP62) which also performs the differential to single-ended conversion of each pair of the IF signals. The second amplification stage consists of a single dual channel opamp (OP61) and provides a further 30dB of amplification. An additional opamp (OP20) is used to generate the reference voltage of 1.65V for the baseband section. Figure 12 shows the location of the baseband components on the PCB and Figure



13 shows the detailed schematic of the baseband amplifier section.

Figure 12 Baseband Amplifier Chain on PCB

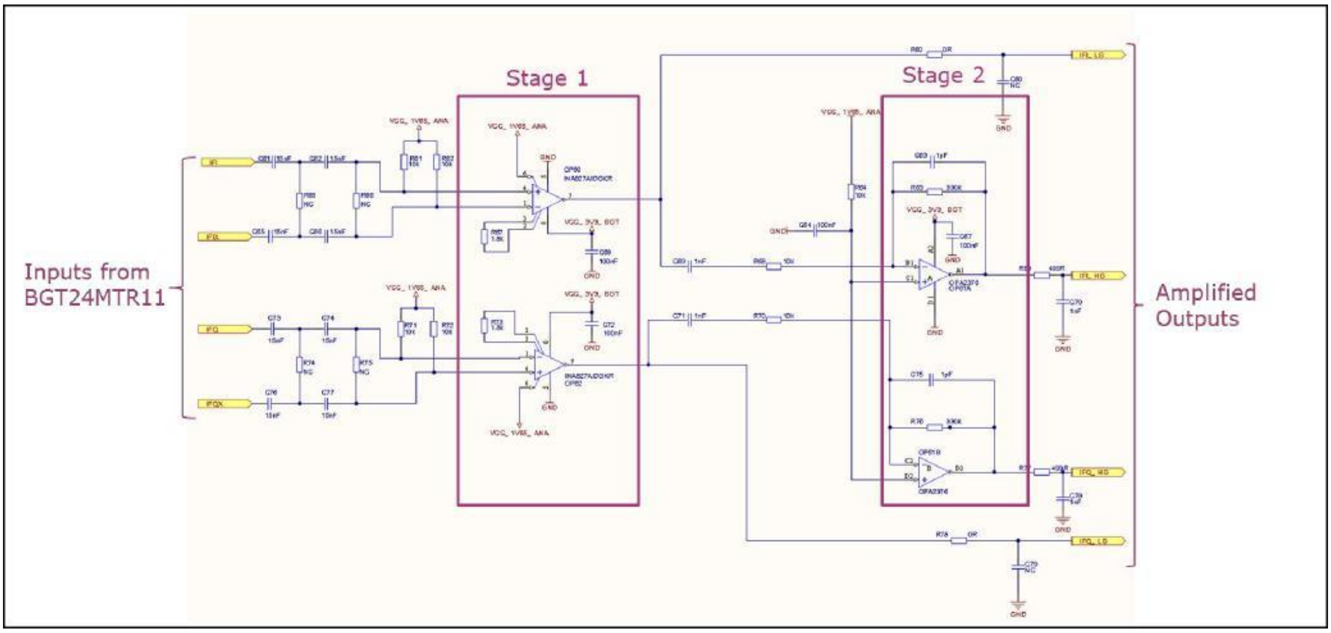


Figure 13 Baseband Amplifier Schematic

The Distance2Go module allows the user to select either the Low Gain (First stage only) or High Gain (First Stage + Second Stage) mode depending upon the target RCS and distance to be detected by simply configuring the MCU pin settings in the software. No hardware changes are needed for this process. Table 4 Lists the MCU pins

associated with each of the gain stages. Use the graphical pin select tool in DAVE software to select the appropriate pins for signal processing.

Table 4 Baseband Amplifiers to MCU Pin Connections

XMC4200 – QFN48 - Port Pin	Pin Function
P14.0	IFI – Low Gain
P14.9	IFQ – Low Gain
P14.4	IFI – High Gain
P14.3	IFQ – High Gain

The gain and bandwidth of the IF stages are fixed and can be manually configured by the user by changing the resistor and capacitor values specified in Table 5.

Table 5 Baseband Amplifier Components and Settings

IF Stage	Designator	Gain	Bandwidth (3-dB)	Configurable Components – I section	Configurable Components – Q section
Stage 1 (Low Gain)	OP60, OP62	34 dB	2 kHz – 200 kHz	C61, C62, C65, C66, R61, R62 (For High Pass Response) R67 – Gain and Low Pass Response	C73, C74, C76, C77, R71, R72 (For High Pass Response) R73 – Gain and Low Pass Response
Stage 1 + Stage 2 (High Gain)	OP60 , OP62+ OP61	64 dB	14 kHz – 120 kHz	All components as mentioned for Stage 1 + C63, C69, R63, R68	All components as mentioned for Stage 1 + C71, C75, R70, R76

4.4.1 Overview - low gain mode

The Distance2Go module in its delivery state is configured to use the Low Gain mode (Stage 1).

Due to limited isolation between the TX and RX of the radar system, there is a feedthrough of the TX signal into the RX part. Due to this effect there is always a dominating low frequency component at the receiver output of the radar IC. The value of this low frequency component depends on the value of the FMCW ramp settings. This low frequency signal will be further amplified by the gain of the baseband section and may completely saturate the radar IF chain (ADCs and further amplifier stages). This effect is inherent to all FMCW radar systems and cannot be eliminated completely in the analog domain. However by using appropriate filtering, the effect of this crosstalk can be minimized. This requires the implementation of filtering stages prior to the amplification of the IF signal by the baseband section. Due to this reason, the baseband section of the Distance2Go module is designed to have a bandpass characteristic. The stage 1 (low gain mode) is designed for a gain of 34dB with a 3dB bandwidth from 2 kHz to 200 kHz. The TX to RX crosstalk effect also limits the minimum distance that can be measured by the radar.

For targets with a RCS around 10m^2, the low gain mode allows to measure distances upto 25m. For targets with a RCS of 1m^2 (corresponding to humans), detection is possible upto 12m but also depends strongly on the measurement environment. In order to change the frequency response of the low gain stage, the components mentioned in Table 5 can be modified on the PCB. The low pass response of this stage is fixed by the amplifiers internal bandwidth. The gain can be changed easily by configuring resistors R67 and R73. Figure 14 shows the frequency response of the low gain stage.

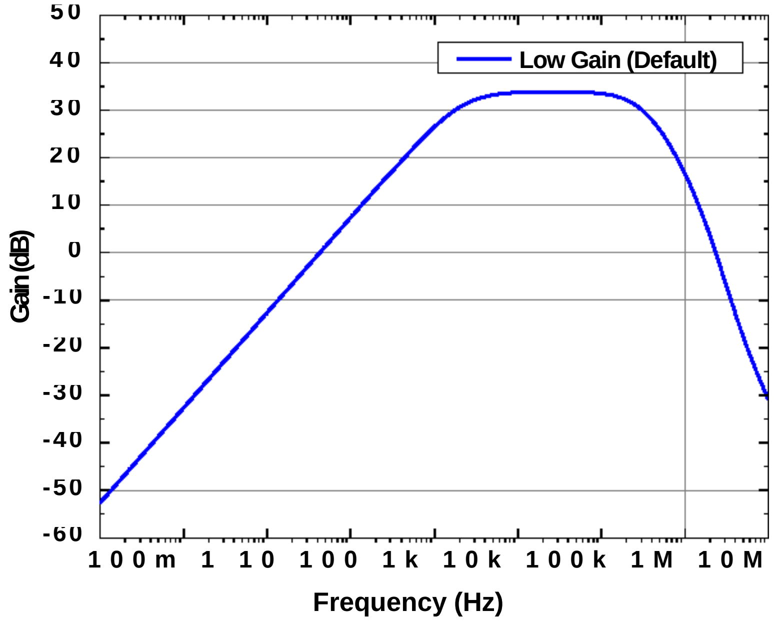


Figure 14 Baseband Frequency Response – Low Gain Mode

4.4.2 Overview - high gain mode

The second amplification stage is optional and may be used depending on the application and the target RCS to be detected. The second IF amplifier is designed for an individual gain of 30 dB and in combination with the first IF stage provides a total IF gain of 64 dB with a 3dB bandwidth from 14 kHz to 120 kHz as shown in

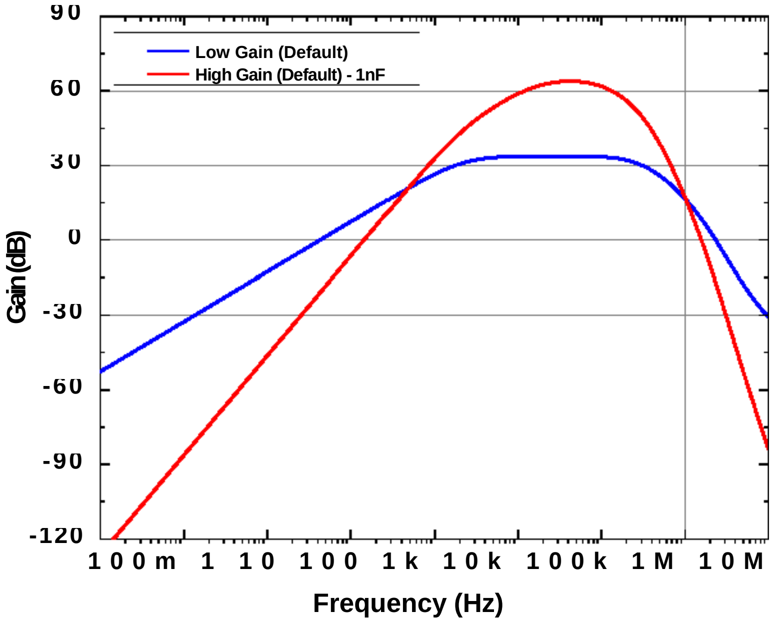


Figure 15.

Figure 15 Baseband Frequency Response – High Gain Mode (C69 = C71 = 1nF – Red Curve)

For short range measurements (< 25m) it is sufficient to use only a single IF amplification stage (low gain mode) thereby keeping the BOM cost low. For long range measurements (>25m), and for target with very low and varying RCS (eg. human beings) the radar may not be able to provide a precise detection depending upon the environmental condition. Also the variation of several parameters (both RF and baseband) over different PCBs and silicon ICs makes the situation more complex. In such cases enabling the high gain mode on the module could improve the detection range. Especially when the IF frequencies are between 5 kHz and 100 kHz, the received signal strength could be improved sufficiently for detection by the radar.

When enabling the high gain mode, it has to be ensured that signals close to DC does not get amplified significantly leading to saturation of the ADCs. This may lead to several spurious signals at the IF output. To minimize the impact of the TX to RX leakage, the high gain mode operation offers a higher, high pass cut of frequency than the first IF stage as shown by the red curve in Figure 15. The operation of the high gain mode is very sensitive to radar operating environment. If the environment surrounding the radar has large number of reflecting objects, all of them will be significantly amplified by the baseband section and may prevent the signal processing algorithm to separate the wanted signal from the clutter.

The enabling of the high gain mode certainly benefits the detection of low RCS targets at longer distances. However for certain targets like trees, grass (Dry grass especially) and other vegetation types and very thin cables which has even smaller RCS, detecting them successfully even at shorter distances becomes extremely challenging due to significantly weak reflected signal. For such applications just by switching to the high gain mode may not be beneficial anymore. Such applications may require modifying the frequency response of the baseband amplifiers in order to achieve larger gain for lower frequencies too.

For short distance measurements targets with very low RCS it is recommended to provide more gain at lower frequencies by changing the highpass corner frequency of the IF section. An easy way to achieve this on the Distance2Go platform is to enable the high gain mode and modify only the capacitors C69 and C71 values. This will reduce the high pass filter cut off frequency and thus provide higher baseband gain for low RCS targets at shorter distances from the radar. Figure 16 gives an example of such a case wherein the high pass filter cut off frequency is changed to 2kHz from the default value of 14kHz by changing the capacitor values of C69 and C71 from 1nF to 100nF (Green Curve). This also provides a much higher gain than the low gain mode for lower frequencies. However doing this will also affect the TX-RX crosstalk component and will impact the minimum distance the radar can measure. In these cases special signal processing techniques need to be applied in the digital domain in order to successfully detect and measure smaller distances to such targets.

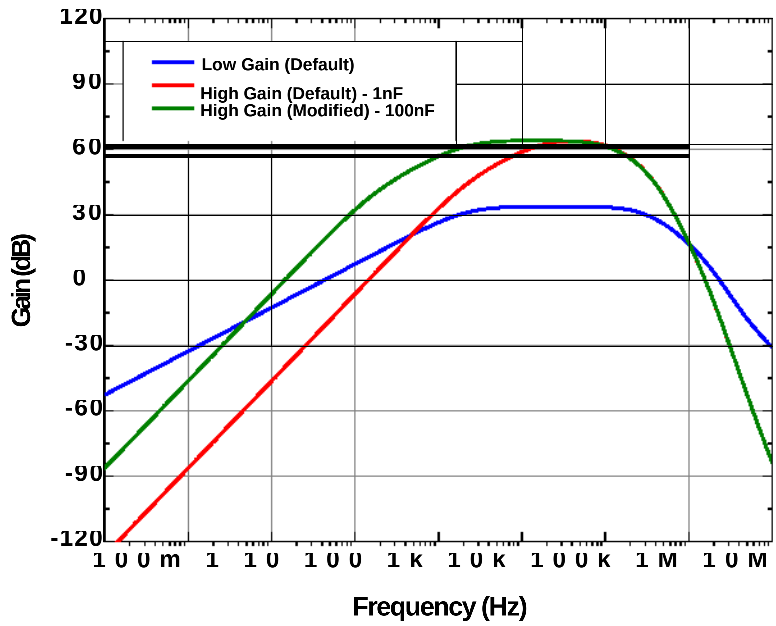


Figure 16 Baseband Frequency Response – High Gain Mode Improved (C69=C71=100nF – Green Curve)

In general the ideas proposed in the preceding sections regarding the use of a second gain stage are only hints to enable the users of the module to easily change the baseband section for different target scenarios, with minimum effort. For a final product design, great care has to be taken to configure both the gain stages independently. There could be situations where the gain of the first stage may be high enough to saturate the second stage completely due to the amplification TX-RX crosstalk. Therefore for situation requiring the use of two stages of amplification, it is recommended to completely redesign the baseband section based on the application requirements and if required modify all the components of the baseband section listed in Table 5.

4.4.3 IF section and FMCW pamp settings

The bandpass characteristics of the IF section is also determined from the FMCW ramp parameter settings. Different ramp settings lead to different IF frequencies for targets at different distances. Table 6 gives an example of IF frequencies produced by stationary targets at particular distances corresponding to different sawtooth type ramp parameters. These IF frequencies are also called as “beat frequencies”. The beat frequencies calculated in the table does not include the Doppler shift.

The beat frequency is calculated from the formula described below

$$\text{Beat Fequeny } (F) = \frac{2 * R * \Delta f}{c * Tr}$$

Where

R = Target Distance in meters

Δf = Ramp Bandwidth in Hz

T_r = Ramp Time in seconds

c = Speed of light in meters/second

Table 6 IF Frequency vs FMCW Ramp Parameters vs Target Distance

Ramp Duration	Ramp Bandwidth	Beat Frequency (Target @ 50cm)	Beat Frequency (Target @ 10m)	Beat Frequency (Target @ 30m)	Beat Frequency (Target @ 50m)
512µs	220 MHz	1.4 kHz	29 kHz	86 kHz	143 kHz
1ms	180 MHz	600 Hz	12 kHz	36 kHz	60 kHz
1ms	220 MHz	733 Hz	14.7 kHz	44 kHz	73kHz
2ms	180 MHz	300 Hz	6 kHz	18 kHz	30kHz
2ms	220 MHz	367 Hz	7.3 kHz	22 kHz	36.5 kHz

4.4.4 Baseband amplifier settings for implementing Doppler radar

The Distance2Go module is optimized for FMCW radar. The firmware delivered with the module nevertheless allows the user to implement also Doppler radar in order to perform simple movement and direction of movement detection. However due to the current high pass filter cut-off frequency settings of both the gain stages, the Doppler Effect produced by very small target movement will not be detected by the radar. Also slow Doppler movements produced by targets at far distances from the radar will not be detected either. The high pass and low pass filter settings that are currently optimized for FMCW case, significantly reduces the detection range of the radar for Doppler applications, especially for slow moving targets. Therefore for Doppler applications, it is recommended to modify the baseband amplifier filter section appropriately to enable the module to detect lower frequencies with sufficient amplification. Once again, as mentioned in section 4.4.2 this can be easily achieved by modifying only the capacitor C69 and C71 values. Table 7 gives an overview of the

Doppler frequencies generated by targets with different speed. The baseband section should be configured accordingly to provide sufficient gain at these frequencies.

Table 7 Doppler Shift Frequencies for Different Speeds using 24GHz Radar

Speed	Km/h	1	1.5	2	2.5	3	4	5	6	8	10
Doppler Shift	Hz	44.4	66.7	88.9	111.1	133.3	177.8	222.2	266.7	355.6	444.4

4.5 Operating BGT24MTR11 in low power mode

The Distance2Go module offers the possibility to operate the BGT24MTR11 in a duty-cycle mode. This is done by enabling/disabling the PMOS (U51) over the Pin 0.5 of the MCU as shown in Figure 17. Toggling this pin allows to switch ON/OFF the power supply to the MMIC over the FET. The signal is low active and has a pull down resistor in place. In its default state the module is already programmed for duty-cycle mode of operation. Please refer to the software guide for more details on the duty cycle procedure and specifications.

It is strongly recommended to use the module in a duty-cycle mode to keep the overall power consumption and thermal dissipation low. The Distance2Go was designed to have a compact form factor. Keeping the BGT24MTR11 always turned ON will heat up the module significantly and could result in undefined behavior. In such cases it is recommended to turn OFF all the unused building blocks inside the BGT24 via the SPI and for short distance measurements reduce the transmit output power to minimum. Also putting the microcontroller in a deep sleep mode when not in operation will help to minimize power consumption and thermal dissipation significantly. The current firmware does not include the settings to put the microcontroller in a power optimized mode and it is completely upto the end-user to define such settings using Infineon's free of charge development tool kit DAVE.

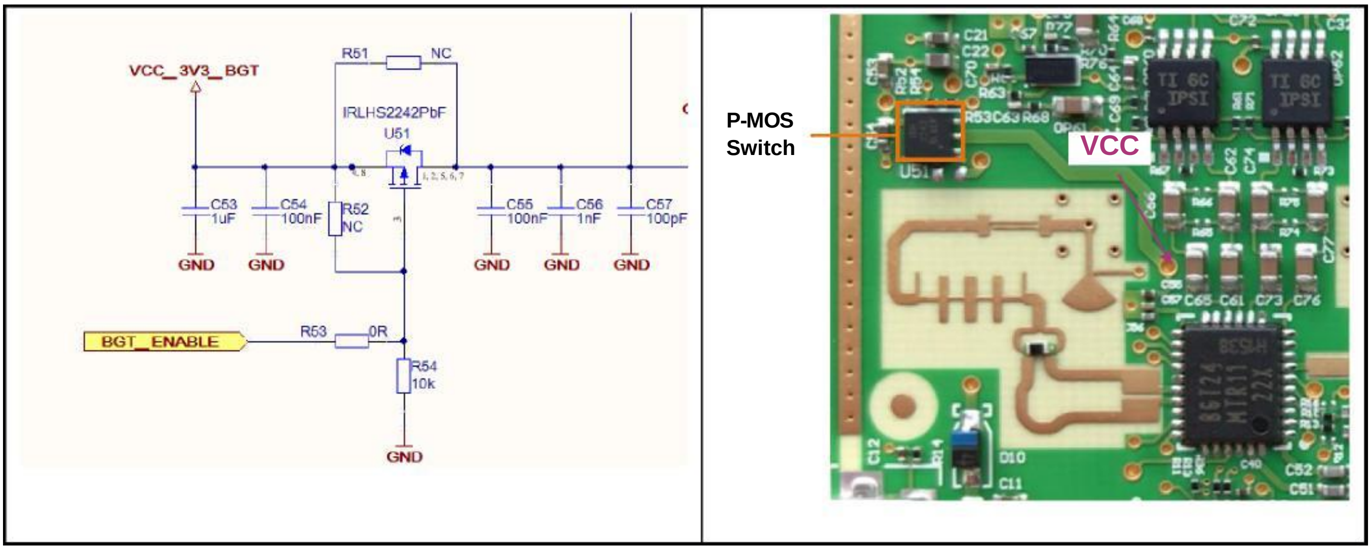


Figure 17 BGT24MTR11 Duty-Cycling Concept

The module also offers a second possibility to turn off completely the BGT24MTR11 and the IF section by using the LDO trigger pins. Please follow the recommendations in Section 4.1 for this procedure. It has to be noted that this mode requires detailed timing analysis for proper signal processing, due to slower start-up time of the LDO and baseband amplifiers when compared to the PMOS. The reduction in power consumption is only minimal since the baseband amplifiers consume very low power.

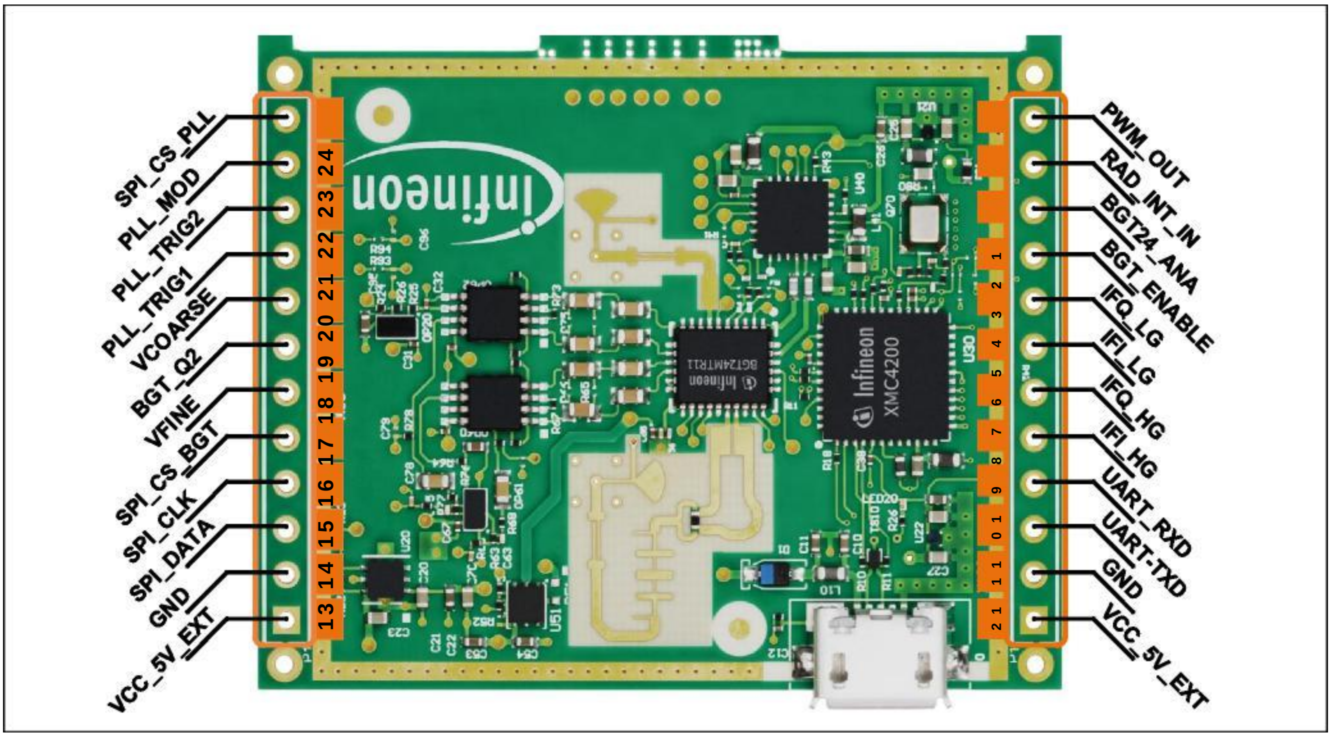


Table 8 External Headers – Pin Description

		Pin DescriptionaemN Signal
		User 1ILxPWM_OUT External User Configurable GPIO with CCU4 Unit (User Configurable)
		2 pin for RAD_INT_INInt GPIO GPIO pin for Interuppt Signals (User Configurable)
		MultiplexerBGT_24_ANA Multiplexer output pin of BGT24MTR11 to read various sensor values
		BGT_ENABLE BGT24MTR11 Duty-Cycling Pin to Enable/Disable the PMOS Switch
		5 BGT24MTR11 Q_G FLIQ BGT24MTR11 BGT24MTR11 Q-Channel - Analog Signal Output – First Gain Stage
		_GIILF BGT24MTR11 I-Channel - Analog Signal Output – First Gain Stage
	IFQ_HG	BGT24MTR11 Q-Channel – Analog Signal Output – Second Gain Stage
	IFI_HG	BGT24MTR11 I-Channel - Analog Signal Output – Second Gain Stage
	UART-RXD	Receive Pin for UART Communication
	UART-TXD	Transmit Pin for UART Communication
	GND	Ground
	VCC_5V_EXT	External -l-5.0V Input Power Supply Pin (Maximum = 5.5V)
	VCC_5V_EXT	External -l-5.0V Input Power Supply Pin (Maximum = 5.5V)

o t e N

5 2

Pin No	Signal Name	Pin Description
14	GND	Ground
15	SPI_DATA	SPI Master Out Slave Input/Output
16	SPI_CLK	SPI Clock Input/Output
17	SPI_CS_BGT	SPI Chip Select Input/Output – BGT24MTR11
18	VFINE	BGT24MTR11 - VCO Fine Tuning Input (0.5V -3.3V)
19	BGT_Q2	BGT24MTR11 Q2 Prescaler output-23kHz
20	VCOARSE	VCO Coarse Tuning Input (0.5V -3.3V)
21	PLL_TRIG1	Multiplexed Input/Output Pins for Ramp Triggers, FSK/PSK Modulation, FastLock, and Diagnostics
22	PLL_TRIG2	Multiplexed Input/Output Pins for Ramp Triggers, FSK/PSK Modulation, FastLock, and Diagnostics
23	PLL_MOD	Multiplexed Input/Output Pins for Ramp Triggers, FSK/PSK Modulation, FastLock, and Diagnostics
24	SPI_CS_PLL	SPI Chip Select Input/Output – LMX2491 PLL

The pin headers enhance the functionality of the module significantly. They allow probing the analog outputs of the sensor module and also probe various other signals provided to the IC. In principle, the accesiblity to several pins on the radar IC and the IF signals available via the external pin headers, allows interfacing the module with an external signal processor. Apart from the on-board user-LED, the external headers provide two additional user configurable GPIO pins from the microcontroller with a number of features, and can be used to drive external shields like the Infineon RGB LED lighting shield.

4.7 User LEDs

The port pin P2.0 of the XMC4200 on the Distance2Go module is connected to an external LED on the antenna side of the PCB.

Table 9 Pins used for the User LEDs

LED	MCU Port Pin
LED31 (LED-RED)	P2.0

4.8 Central microcontroller unit – XMC4200

The Distance2Go platform uses an XMC4200 32-bit ARM® CortexTM-M4 MCU to perform the radar signal processing. The XMC4200 takes care of communication with all the sub systems on the radar module, enables data acquisition, performs the complete radar signal processing (including sampling and FFT) and communicates the results via its UART or USB interface to an external device. An XMC4200 in a 48-pin VQFN package is used, featuring an 80MHz CPU Frequency, 256kB flash and 40kB RAM. Two 12-bit Analog-Digital Converters (VADC) with 8-channels each helps to implement the radar signal sampling and also acquire the various sensor data from the BGT24MTR11 MMIC. The XMC4200 has aUSB 2.0 device interface which allows communicating with a PC directly.

The XMC4200 device is a member of Infineon's high-end XMC4000 family of microcontrollers based on the ARM® CortexTM-M4 processor core. The XMC4000 is a family of high performance and energy efficient microcontrollers optimized for Industrial Connectivity, Industrial Control, Power Conversion and Sense & Control. Figure 19 shows a system block diagram of the XMC4000 series MCUs. Please refer to [2] for detailed information on the XMC4200 microcontroller used on the Distance2Go module.

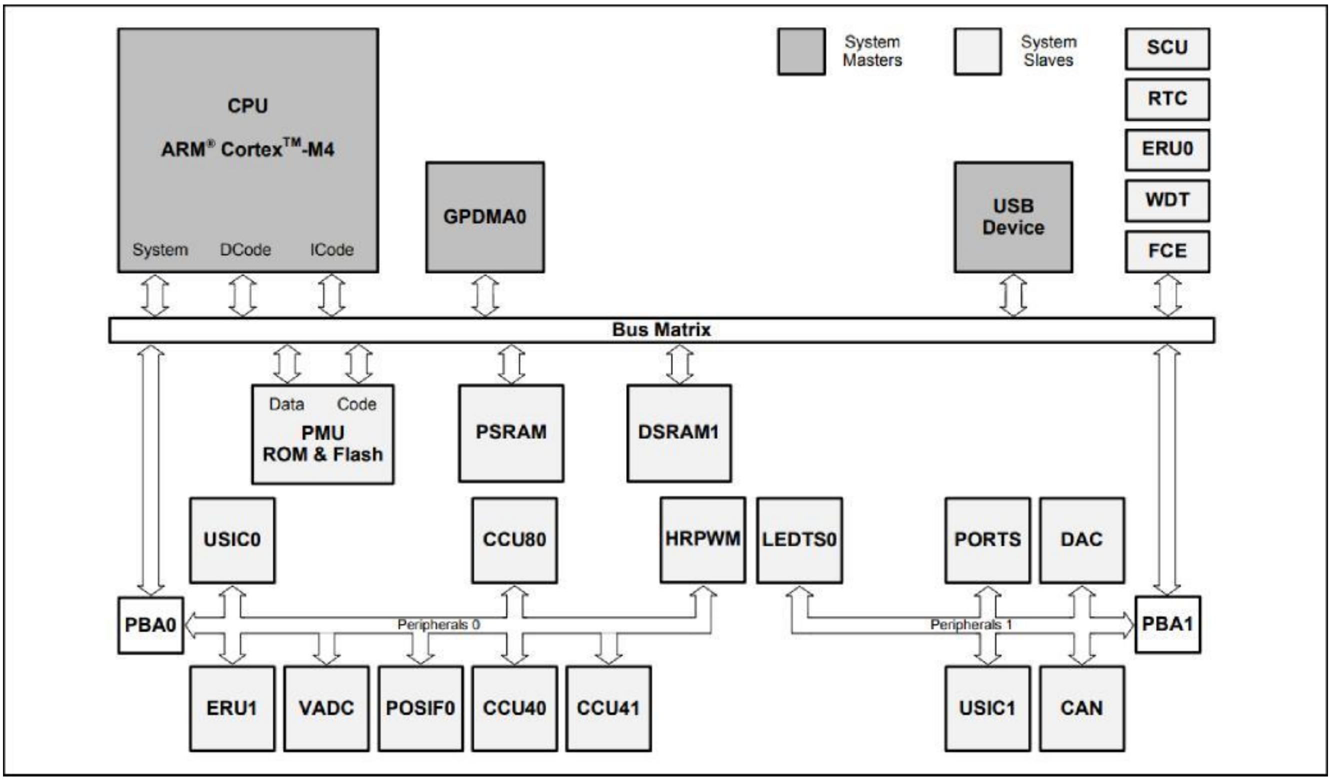


Figure 19 XMC4200 System Block Diagram

4.9 Onboard debugger and UART connection

The Distance2Go platform has an onboard debugger on a breakable board. The debugger supports 2-pin Serial Wire Debug (SWD) and UART communication. Both require the installation of Segger's J-Link Driver which is part of the DAVETM installation. DAVETM is a high-productivity development platform for the XMC microcontroller families to simplify and shorten SW development. It can be downloaded at www.infineon.com/dave . The latest Segger J-Link Driver can be downloaded at http://www.segger.com/jlink-software.html .

During installation of the J-Link driver you will be asked for the installation of optional components. For support of the UART communication take care to install the CDC USB driver (Composite Device Class). Therefore select the option **"Install USB Driver for J-Link-OB with CDC"** as shown in Figure 20

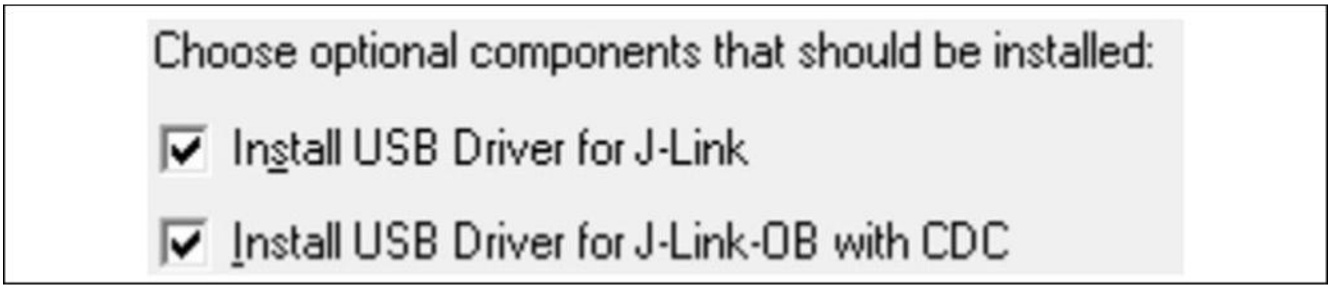


Figure 20 Recommended Installation Options for the J-Link driver

Table 10 shows the pin assignment of the XMC4200-VQFN48 MCU used for debugging and UART Connection. The on-board debugger section supports communication between a PC/laptop and target XMC device via a UART-to-USB Bridge). Therefore the UART pins of the target XMC4200 on the Radar main board is connected to the TX/RX pins of the debug connector. The TX pin of the debugger MCU is connected to the RX pin of the target XMC 4200 MCU. RX pin of the debugger is connected to the TX pin of the XMC target device.

Table 10 XMC4200 Pins used for Debugging and UART Communication

SNO	Port Pin	Pin Function
1	TMS (Pin 33)	Data pin for Debugging via SWD/SPD
2	TCK (Pin 34)	Clock pin for Debugging via SWD
3	0.1	Transmit Pin for UART Communication
4	0.0	Receive Pin for UART Communication

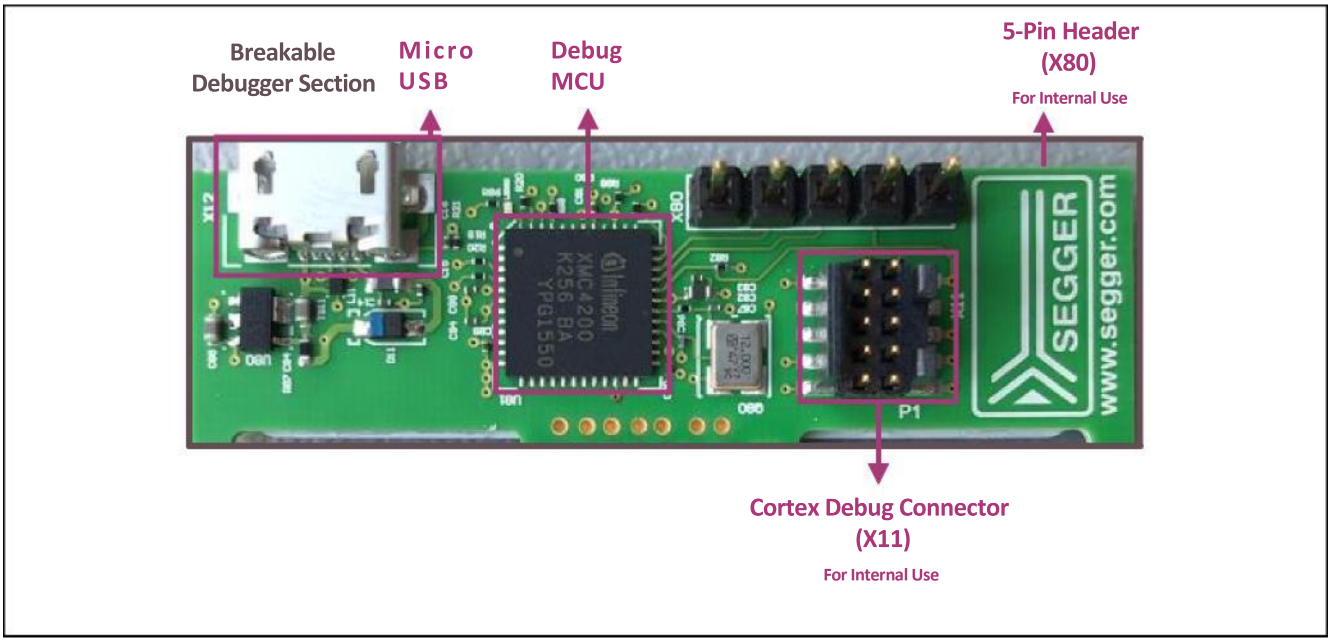


Figure 21 Breakable On-Board Debugger Section

The connectors X11 (Cortex-10 Pin) and X80 (5-Pin Header) on the breakable debugger board were used for internal development and testing purpose and not recommended for customer use. The debugger section consumes typically 85mA from a 3.3V supply.

5 PCB production data

The next pages show the schematic of all the sections of the Distance2Go module and also list the Bill of Materials (BOM) used for production. A high resolution pdf of the schematic can be downloaded online.

5.1 Schematic

Figure 22 - Figure 31 show the schematic of the various sections of the Distance2Go demo board.

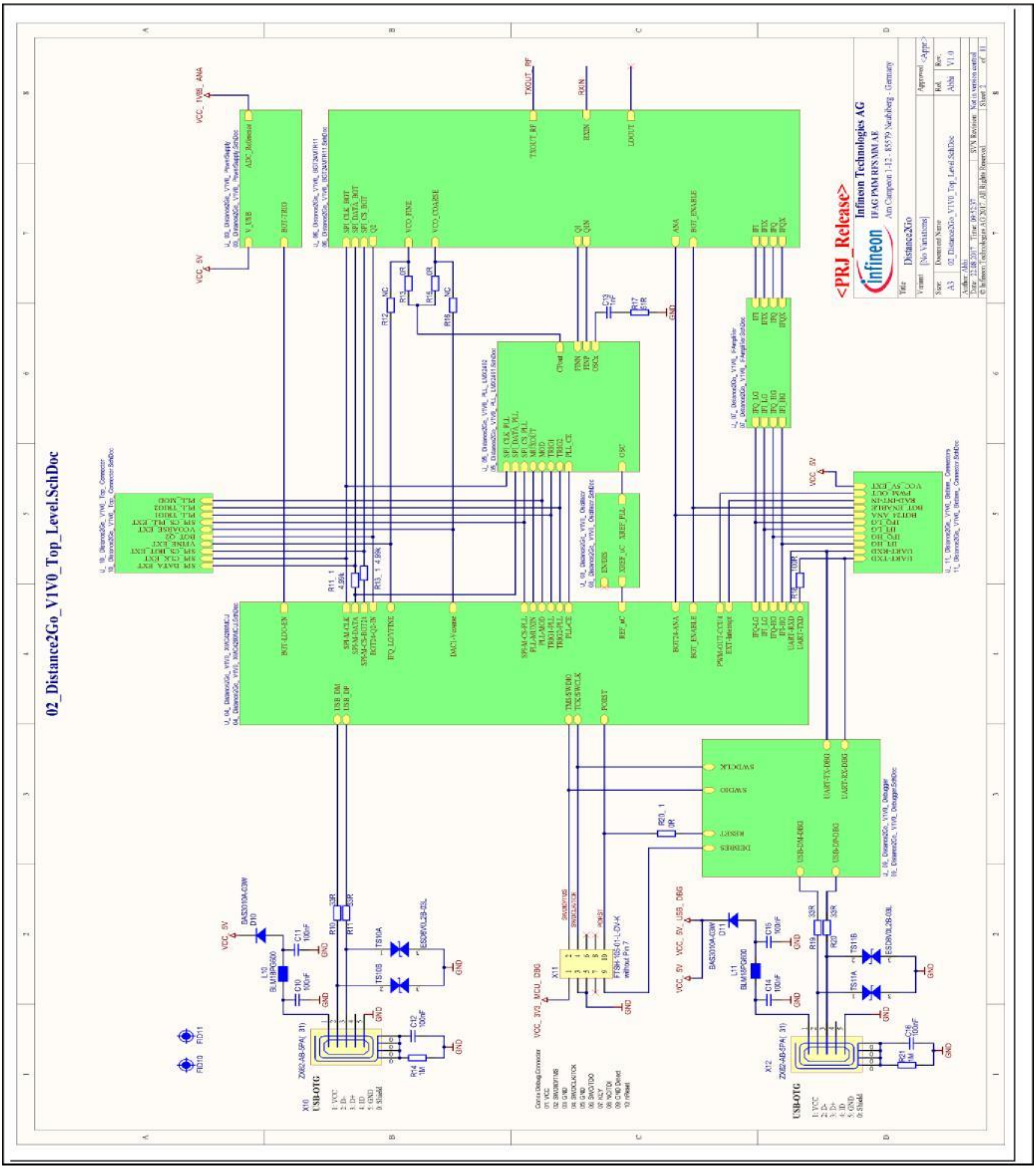


Figure 22 Distance2Go Module - Top Level Schematic

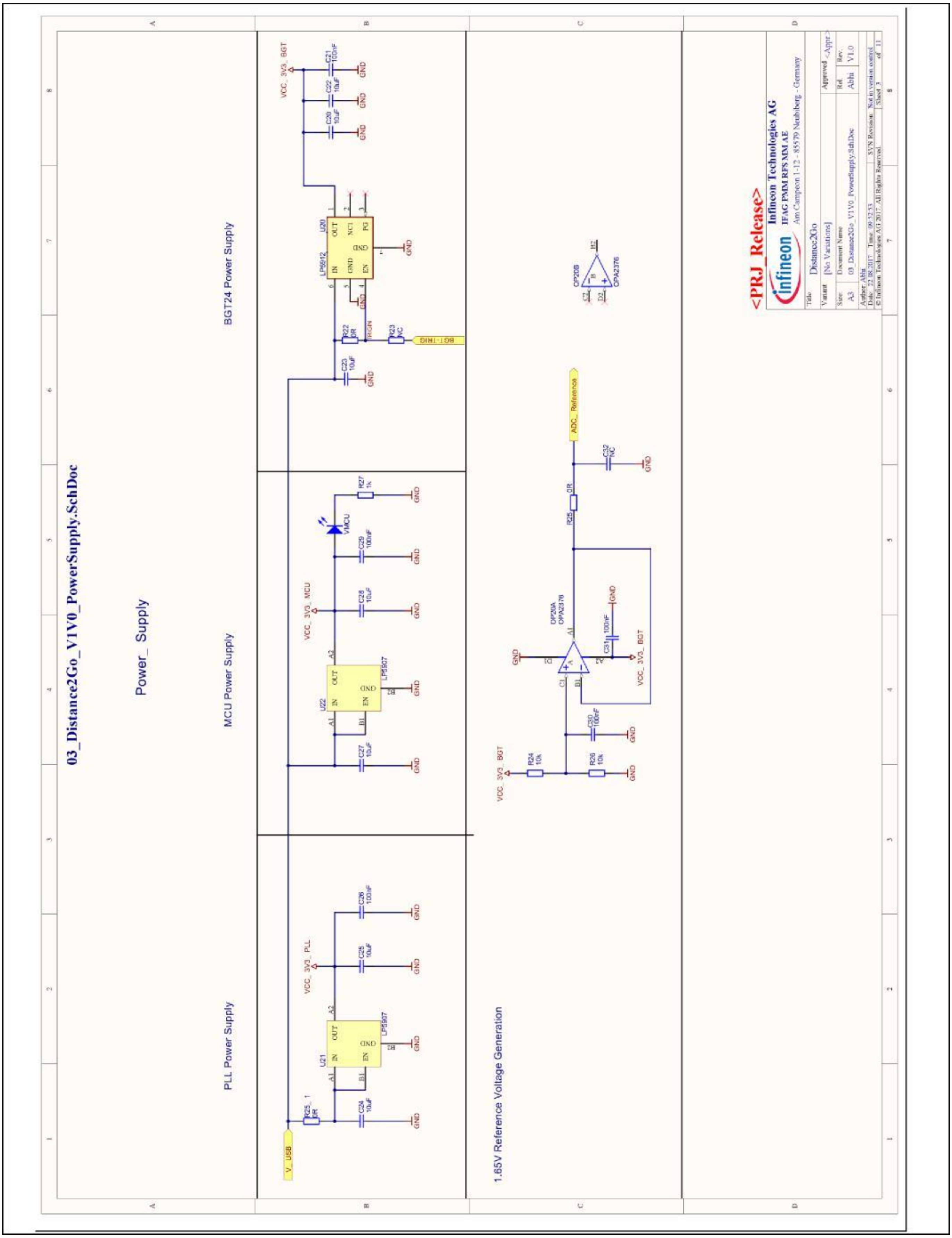


Figure 23 Schematic - Power Supply Section

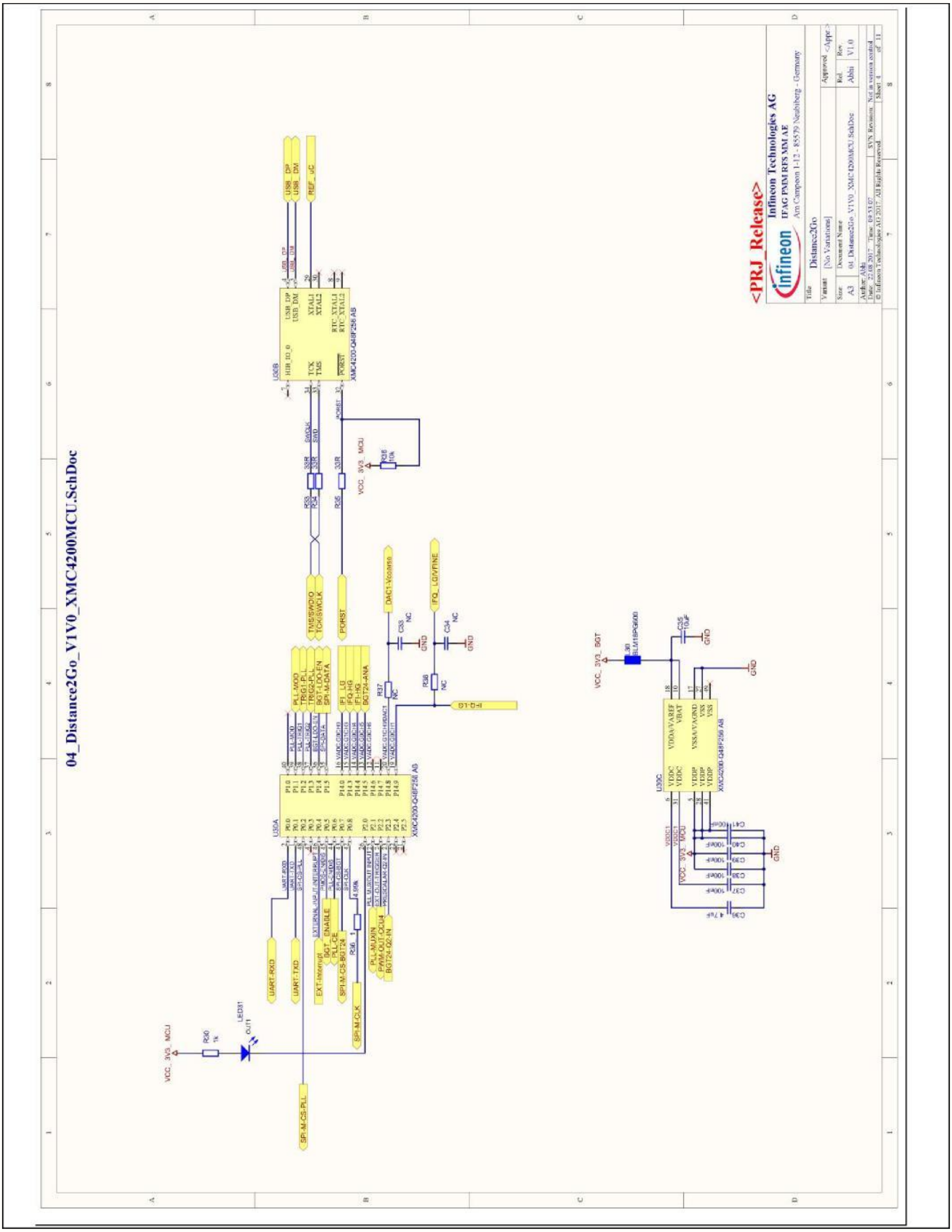


Figure 24 Schematic - XMC4200 Microcontroller Section

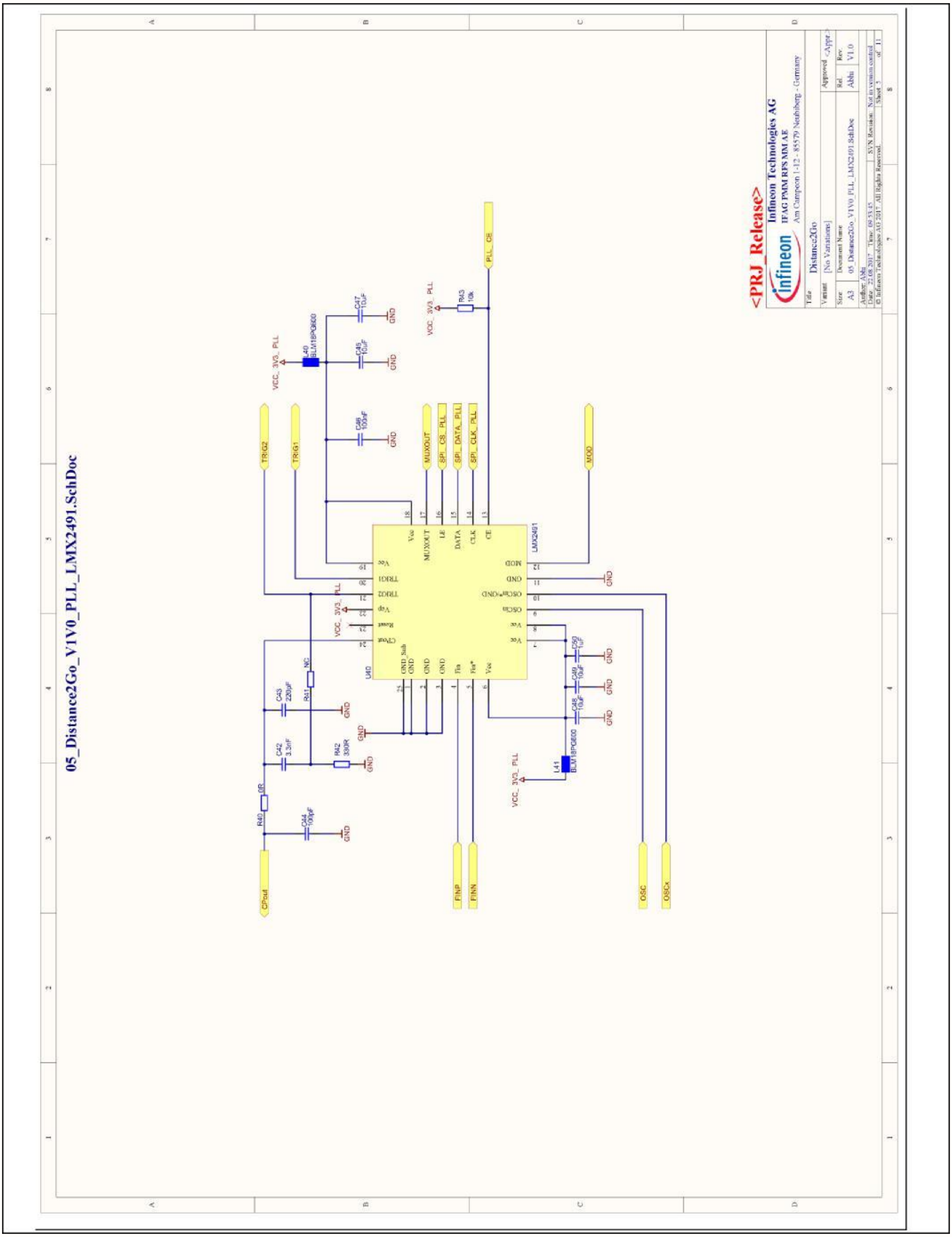


Figure 25 Schematic - LMX2491 PLL Section

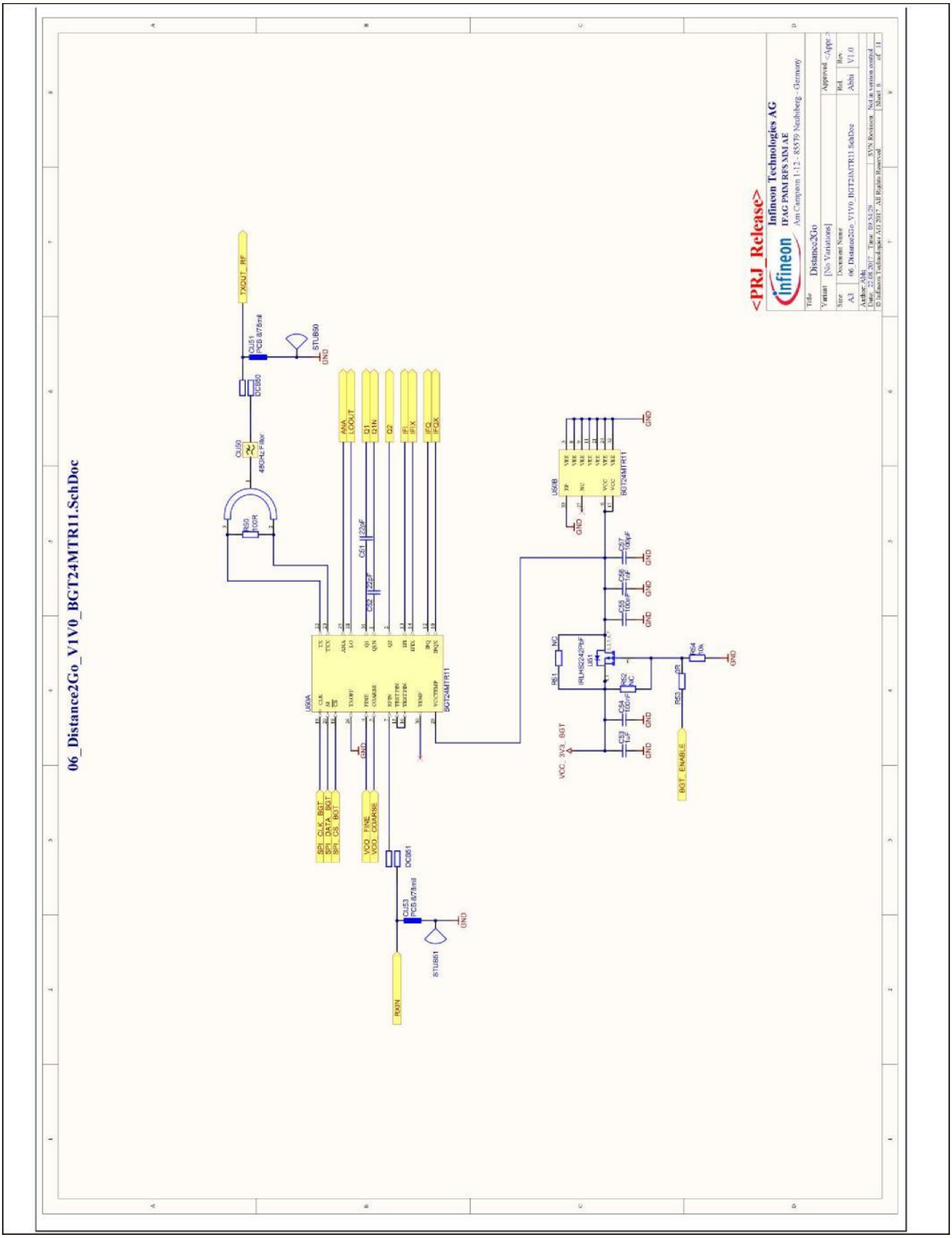


Figure 26 Schematic - BGT24MTR11 24GHz Radar MMIC Section

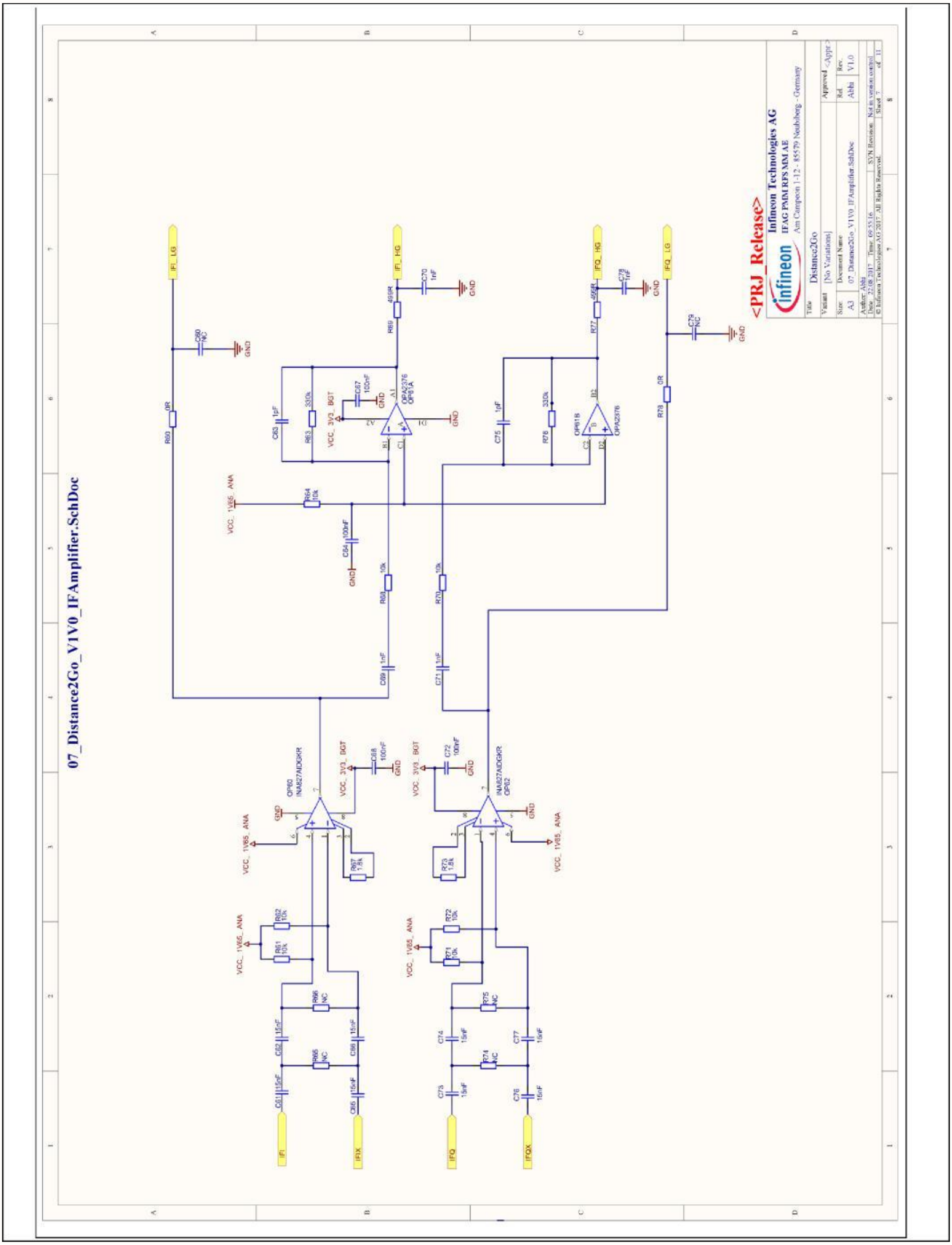


Figure 27 Schematic - IF Amplifier Section

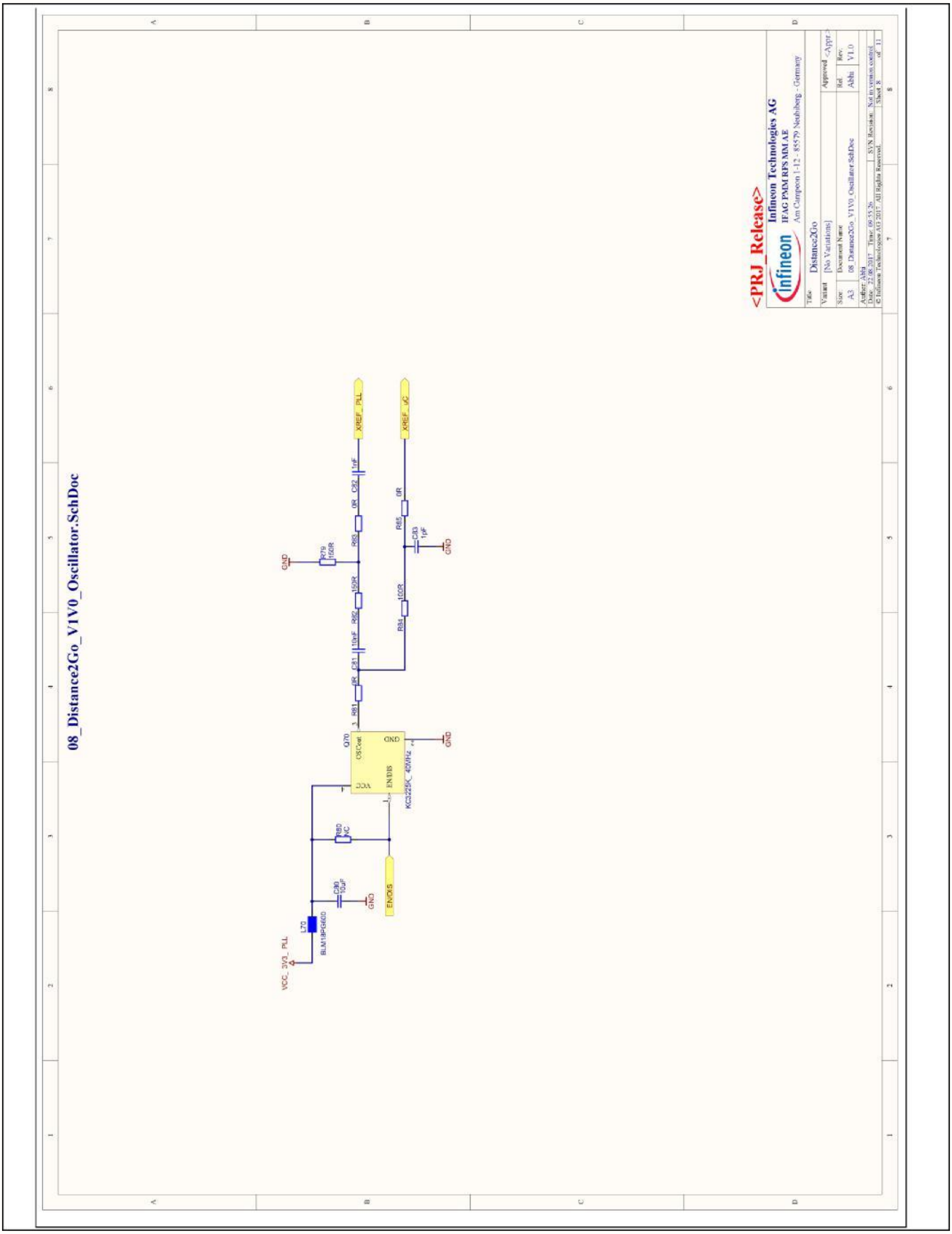


Figure 28 Schematic - Reference Oscillator Section

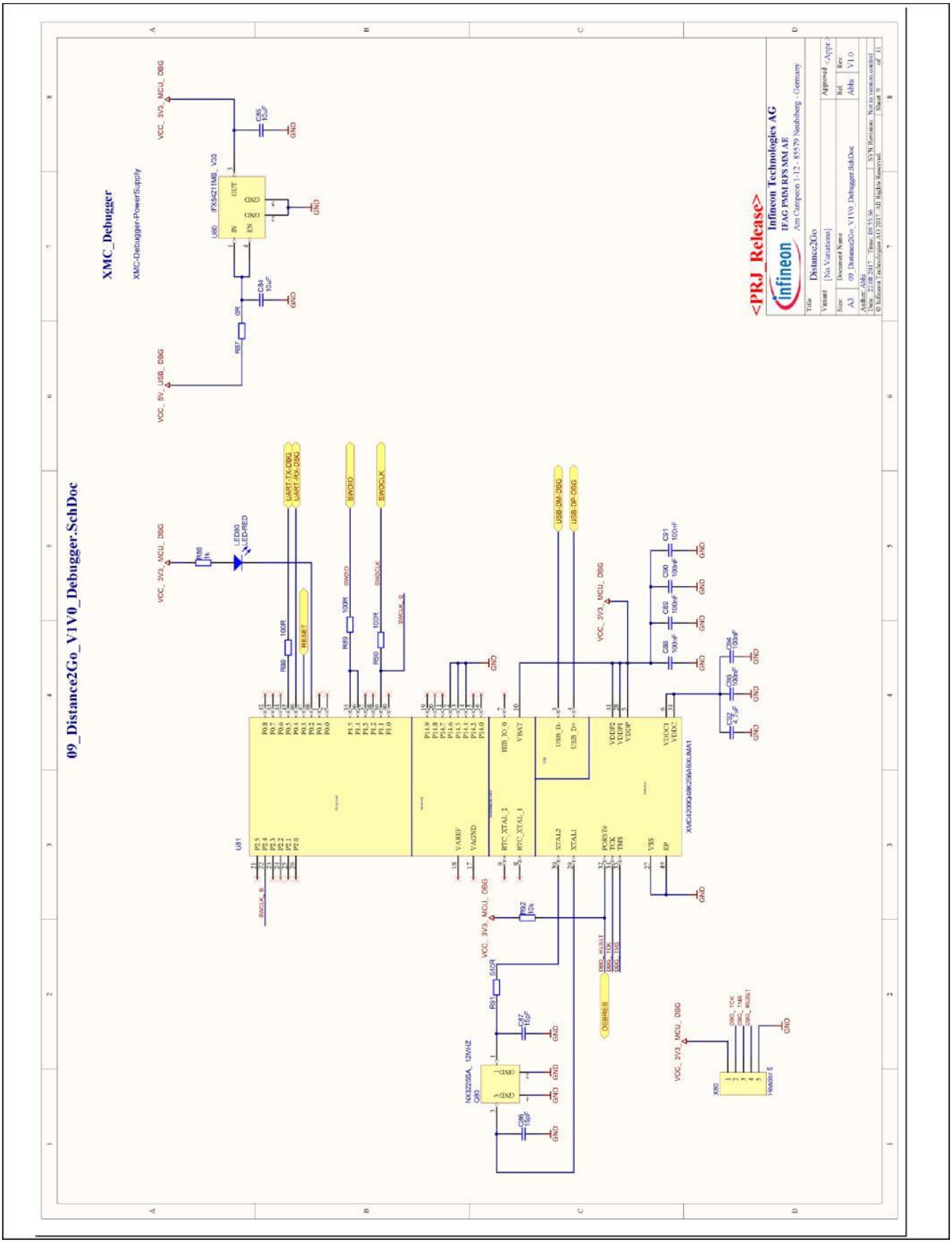


Figure 29 Schematic - On-board Debugger Section

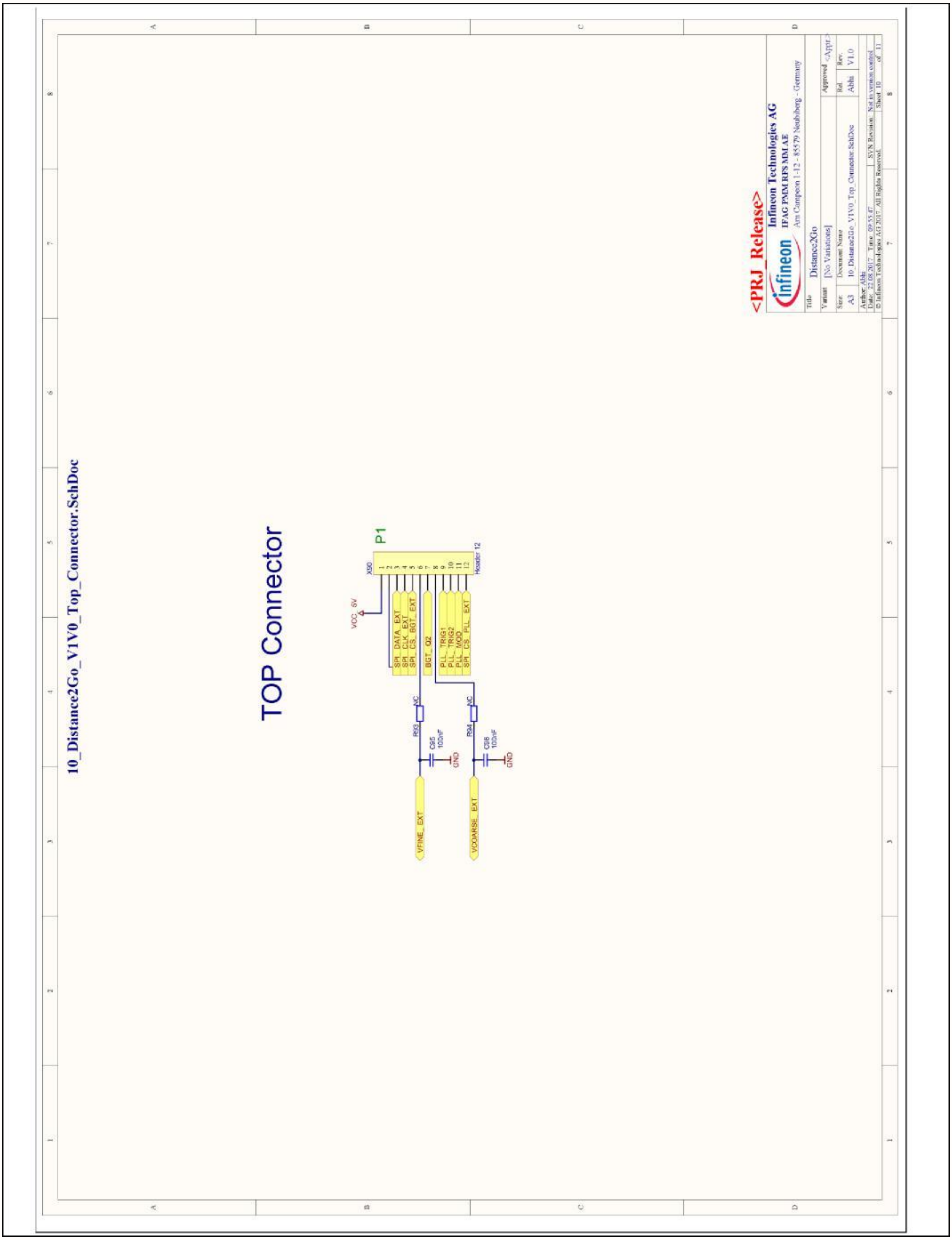


Figure 30 Schematic - External Connector - Top

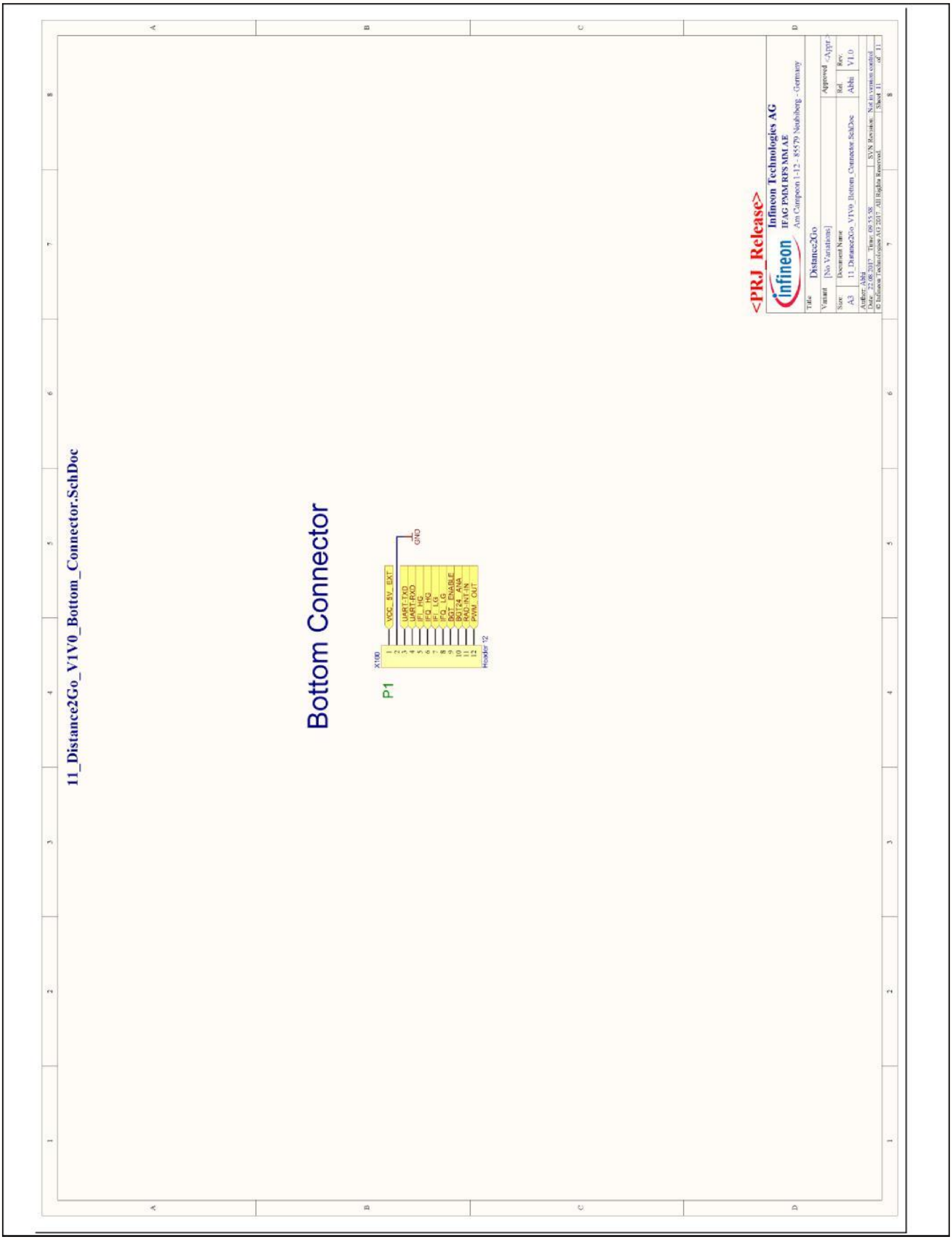


Figure 31 Schematic - External Connector - Bottom

5.2 Bill of Materials (BOM)

Table 11 Distance2Go – Bill of Material

Designator	Component	Package	Description	Quantity
C10, C11, C21, C26, C29, C30, C54, C64	CAP-100nF-50V ±10%-0402	0402	Capacitor	8
C12, C14, C15, C16, C31, C37, C38, C39, C40, C41, C46, C55, C67, C68, C72, C88, C89, C90, C91, C93, C94	CAP-100nF-25V ±10%-0201	0201	Capacitor	21
C13, C56, C70, C78	CAP-1nF-25V ±10%-0201	0201	Capacitor	4
C20, C22, C23, C24, C25, C27, C28, C35, C45, C47, C48, C49, C80, C84, C85	CAP-10uF-10V ±20%-0402	0402	Capacitor	15
C32, C33, C34	Not Connected (NC)	0201	Capacitor	3
C36, C92	CAP-4.7uF-10V ±10%-0402	0402	Capacitor	2
C42	CAP-3n3F-25V ±10%-0201	0201	Capacitor	1
C43	CAP-220pF-50V ±5%-0201	0201	Capacitor	1
C44, C57	CAP-100pF-25V ±5%-0201	0201	Capacitor	2
C50, C53	CAP-1uF-10V ±10%-0402	0402	Capacitor	2
C51, C52	CAP-22pF-50V ±5%-0402	0402	Capacitor	2
C60, C79	Not Connected (NC)	0201	Capacitor	2
C1, C62, C65, C66, C73, C74, C76, C77	CAP-15nF-50V ±10%-0603	0603	Capacitor	8
C63, C75, C83	CAP-1pF-25V ±0.1%-0201	0201	Capacitor	3
C69, C71	CAP-1nF-50V ±10%-0603	0603	Capacitor	2
C81	CAP-10nF-16V ±10%-0201	0201	Capacitor	1
C82	CAP-1nF-16V ±10%-0201	0201	Capacitor	1
C86, C87	CAP-15pF-25V ±5%-0201	0201	Capacitor	2
C95, C96	Not Connected (NC)	0201	Capacitor	2
R10, R11, R19, R20, R33, R34, R35	RES-33R-25V ±1%-0201	0201	Resistor	7
R11_1, R13_1, R36_1	RES-4.99k-25V ±1%-0201	0201	Resistor	3
R12, R16, R23, R80	Not Connected (NC)	0201	Resistor	4
R13, R15, R20_1, R22, R25, R40, R53, R60, R78, R81, R83, R85	RES-0R-25V ±1%-0201	0201	Resistor	12
R1, R21	RES-1M-25V ±1%-0201	0201	Resistor	2
R17	RES-51R-25V ±1%-0201	0201	Resistor	1
R18, R84, R88, R89,	RES-100R-25V ±1%-0201	0201	Resistor	5

Table 11 Distance2Go – Bill of Material

Designator	Component	Package	Description	Quantity
R90				
R24, R26, R36, R43, R54, R61, R62, R64, R68, R70, R71, R72, R92	RES-10k-25V ±1%-0201	0201	Resistor	13
R25_1, R87	RES-0R-50V ±1%-0402	0402	Resistor	2
R27, R30, R86	RES-1k-25V ±1%-0201	0201	Resistor	3
R37, R38, R93, R94	Not Connected (NC)	0201	Resistor	4
R41, R65, R66, R74, R75	Not Connected (NC)	0201	Resistor	5
R42	RES-330R-25V ±1%-0201	0201	Resistor	1
R50	RES-100R-50V ±1%-0402	0402	Resistor	1
R51	Not Connected (NC)	0402	Resistor	1
R52	Not Connected (NC)	0201	Resistor	1
R63, R76	RES-330k-25V ±1%-0201	0201	Resistor	2
R67, R73	RES-1.8k-25V ±1%-0201	0201	Resistor	2
R69, R77	RES-499R-25V ±1%-0201	0201	Resistor	2
R79, R82	RES-150R-25V ±1%-0201	0201	Resistor	2
R91	RES-510R-25V ±1%-0201	0201	Resistor	1
D10, D11	BAS3010A-03W	SOD-323	Medium Power Schottky Diode	2
L10, L11, L30, L40, L41, L70	BLM18PG600	0603	Chip Ferrite 60 Ohm @ 100MHz	6
LED31	KPG-0603PBC-TT-5MAV	0201	LED-BLUE	1
LED80	KPG-0603SEC-E-TT	0201	LED-RED	1
OP20, OP61	OPA2376AIYZD	DSBGA-8	Precision, Low Noise, Low Quiescent Current Operational Amplifier	2
OP60, OP62	INA827AIDGK	MSOP-8 (VSSOP8)	Precision, G>5, 200uA, 2.7-V to 36-V Supply Instrumentation Amplifier	2
Q70	KC3225K40.0000C1GE00	SMD 3.2mmx2.5mm	Standard Surface Mount Clock Oscillators	1
Q80	NX3225SA-12.000M-STD-CRS-2	SMD 3.2mmx2.5mm	Surface Mount Type Crystal Unit	1
TS10, TS11	ESD8V0L2B-03L	TSLP-3-1	ESD Protection Diode	2
U20	LP5912-3.3DRVT	WSON-6	500-mA Low-Noise, Low-I_Q LDO	1
U21, U22	LP5907UVX-3.3/NOPB	DSBGA-4	250-mA Ultra-Low-	2

Table 11 Distance2Go – Bill of Material

Designator	Component	Package	Description	Quantity
			Noise, Low-I_Q LDO	
U30	XMC4200-Q48K256 AB	PG-VQFN48-53	80 MHz MCU with 256 KByte Program Memory, 40 KByte SRAM, 32-bit ARM® CortexTM-M4 (Main MCU)	1
U40	LMX2491RTW	WQFN-24 EP	6.4GHz Low Noise Fractional N PLL with Ramp/Chirp Generation	1
U50	BGT24MTR11	VQFN32-9	24GHz Transceiver IC with 1 TX and 1RX	1
U51	IRLHS2242TR	PQFN6-EP	20V Single P-Channel HEXFET Power MOSFET	1
U80	IFX54211MB V33	SCT-595-5	High PSSR Low Dropout Linear Voltage Regulator	1
U81	XMC4200-Q48K256AB	PG-VQFN48-53	80 MHz MCU with 256 KByte Program Memory, 40 KByte SRAM, 32-bit ARM® CortexTM-M4 (Debugger-MCU)	1
VMCU	KPG-0603CGC-TT	0201	LED-GREEN	1
X10, X12	ZX62-AB-5PA (31)	SMD Micro-USB	Micro-USB Type AB	2
X11	FTSH-105-01-L-DV-K	2x5 Pins – 1.27mm	2x5 Pin header	1
X80	THT RM 2,54mm	THT, 1x5 Pins – 2.54mm	1x5 Pin header	1
X90, X100	THT RM 2,54mm	THT, 1x12 Pins – 2.54mm	1x12 Pin header	2

6 Measurement results

A number of Distance2Go demo boards were measured in an open outdoor environment. This section gives an overview of the measurement setup and presents a summary of the results for targets with two different cross sections (1m^2 and 10m^2)

6.1 Measurement setup

Figure 32 shows the measurement setup

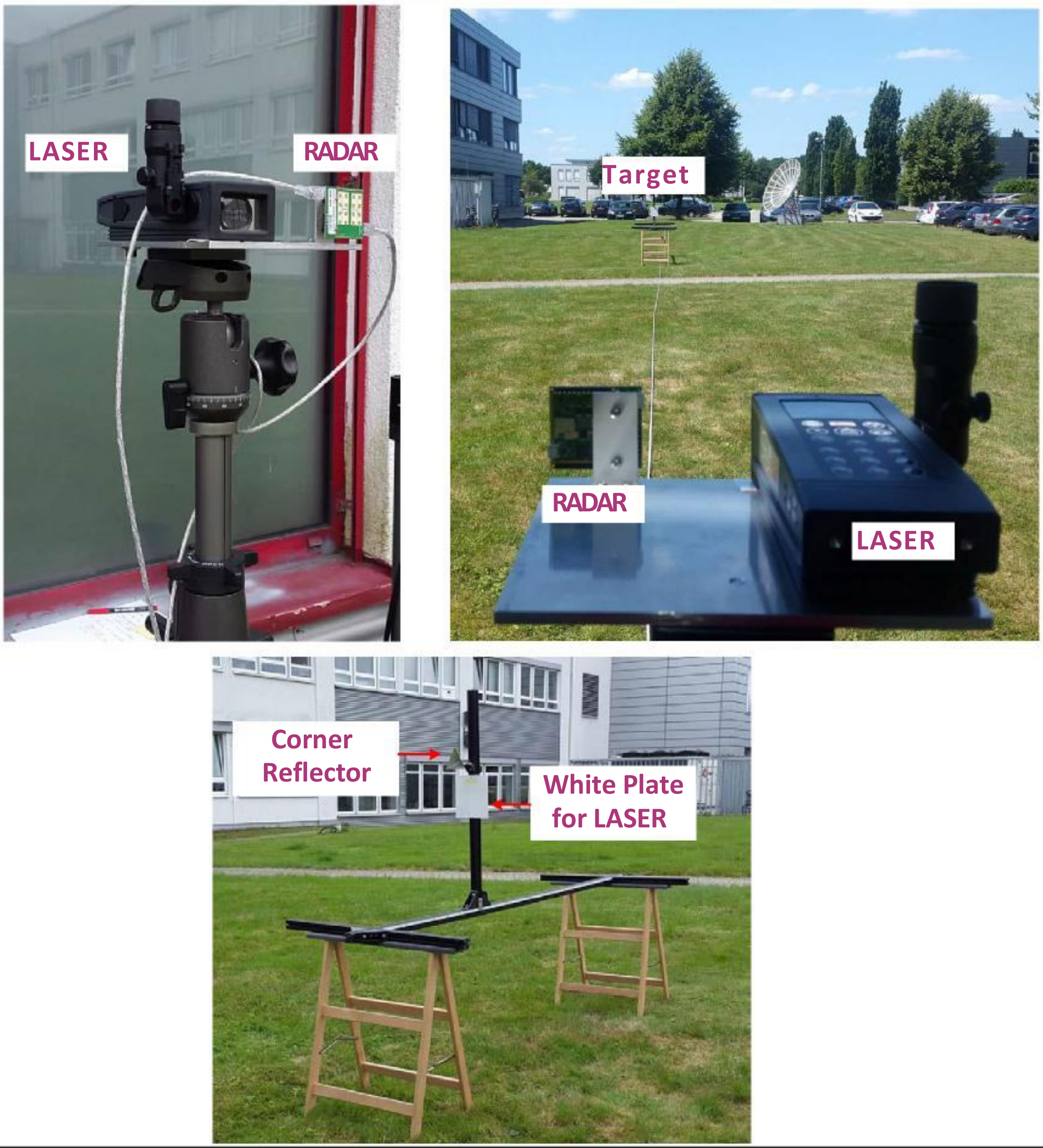


Figure 32 Distance2Go – Outdoor Measurement Setup

The radar module is mounted on an aluminium plate together with a hand-held laser meter (DISTO pro4a from Leica Geosystems). The laser meter has a typical distance measurement accuracy of ± 1.5mm. Radar module and laser meter are both mounted on a tripod. The aluminium plate could be adjusted horizontally with a level. The radar height was typically set between 1.40m to 1.50m, which is roughly the height of the shoulder of an adult person. The radar module was connected with two USB cables. One for DC and communication and a second for DC supply to ensure that enough DC power was available at the module. Radar and laser meter were aligned to a radar target placed on the opposite side on a mechanically adjustable rack, where a corner reflector with RCS = $1m^2$ was mounted. This target is roughly comparable to the RCS of an adult person. A measuring tape on the ground was used to get the radar target in the right position and distance, while all precise distance measurements were made with the laser meter. The measurements were also performed with a corner reflector with RCS = $10m^2$. The radar settings used for the measurements are listed in Table 12.

Table 12 Sensor Settings for Outdoor Measurements

Parameter	Value
Transmitter Output Power	Set to Maximum via SPI
Receiver LNA Gain	Set to High via SPI
FMCW Chirp Type	Sawtooth
FMCW Chirp Bandwidth	220 MHz
FMCW Chirp time	1.5ms
Duty-Cyle Mode	Enabled
IF Stage	Low Gain Mode (Only 1st IF Stage Used)
Firmware Version and Type	Firmware 1 – Standard FMCW – Release Aug 2017
Hardware Version	Distance2Go_V1.0_27062017_SNR: 0006

6.2 Measurement results

Sections below summarize the measurements results of the radar module for each target case and compare them with Laser measurements.

6.2.1 Target with RCS of $1m^2$

For targets with a radar cross section of $1m^2$, the Distance2Go was able to detect them upto 16m. Due to the fundamental limitation of FMCW radar as discussed in section 4.4.1, the minimum distance that could be measured by the module was around 50cms. Between 50cm and 7m the measurement accuracy was better than ±20cm. As the target moved beyond 7m, the accuracy reduced to ±30cm. Beyond 16m it becomes extremely challenging to detect targets with such low radar cross section. Figure 33 shows the measurements results and the accuracy of the radar measurements in comparison to laser measurements.

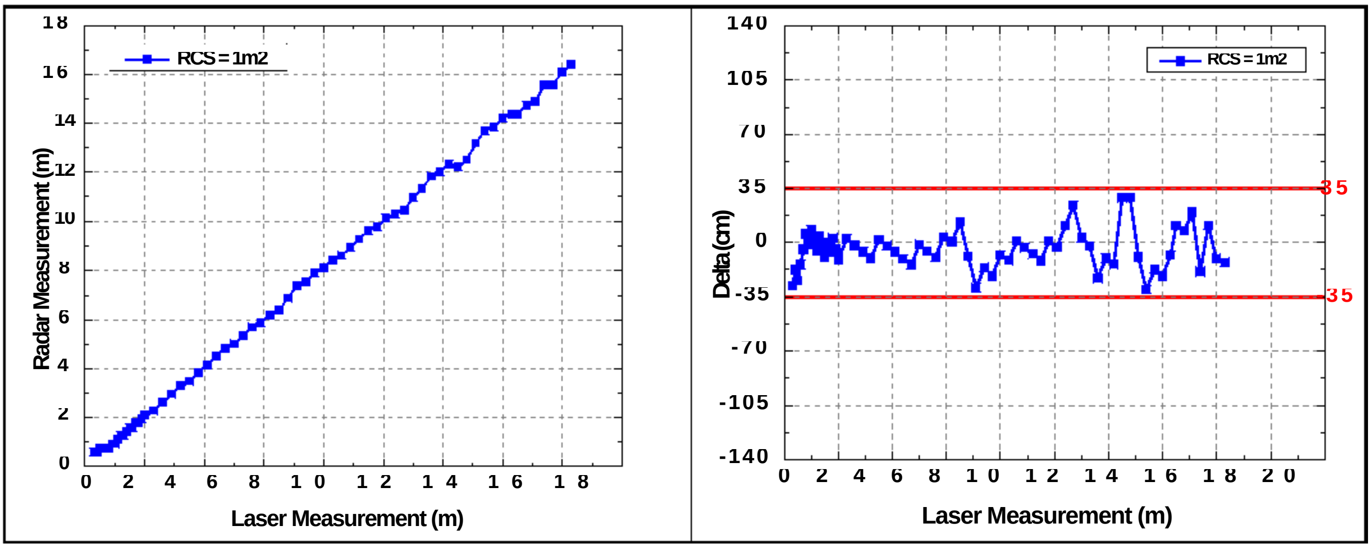


Figure 33 Radar vs Laser Distance Measurements – Target with RCS = $1m^2$

Note: All the measurements were performed in an open outdoor environment with minimum background clutter.

For indoor measurement cases, like with all FMCW radar, the maximum detection range of human targets will reduce significantly. It becomes very hard to quantify the maximum detection range in such indoor measurement cases reliably due to unknown levels of background clutter specific to each environment. Also the variation of several radar parameters like transmitter output power, receiver gain and antenna gain from PCB to PCB at these high microwave frequencies further complicates the scenario.

6.2.2 Target with RCS of $10m^2$

Figure 34 shows the distance measurement results for a corner reflector target with RCS = $10m^2$. It can be observed that as the RCS increases, the measurement accuracy improves too. In this case, the module was able to detect the target upto 25m with an overall accuracy of ±20cm.

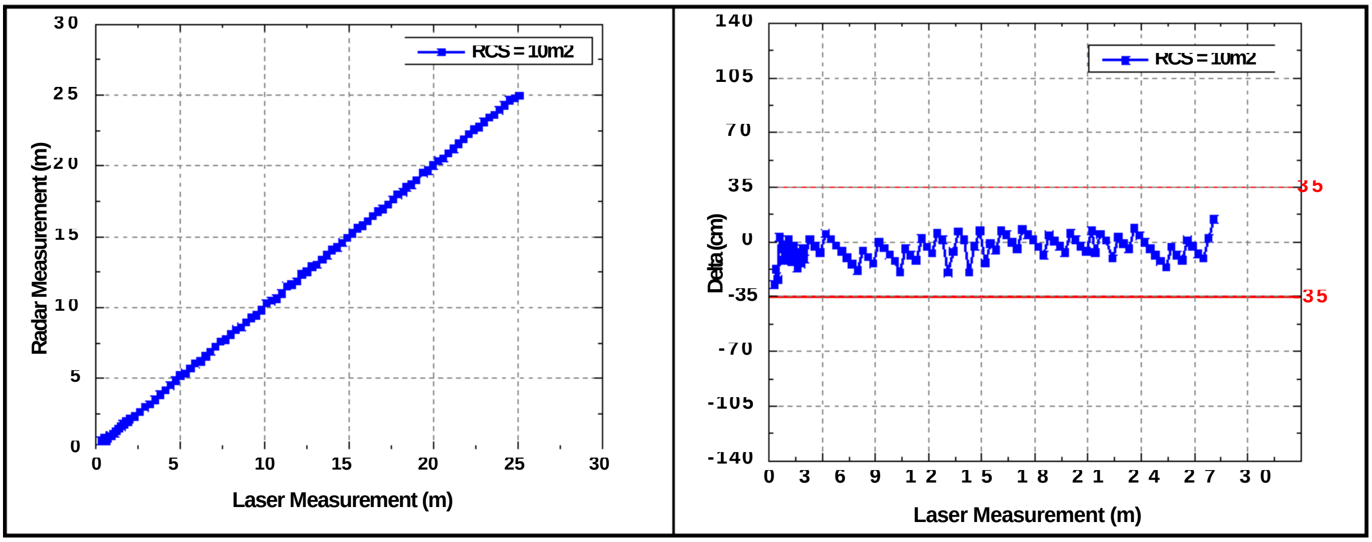


Figure 34 Radar vs Laser Distance Measurements – Target with RCS = $10m^2$

All the above measurements were performed with the Low Gain Mode of the Baseband Section. Based on the measurement environment an improvement in the the maximum detection range of the radar may be possible by enabling the High Gain Mode.

7 Software and firmware description

The Distance2Go demo board is bundled out with firmware supporting different radar applications. The package includes the project and source codes created with Infineons free development tool kit DAVE and an interactive Graphical User Interface (GUI) for the following applications

- Frequency Modulated Continuous Wave (FMCW) Radar based Distance Measurement
- Doppler based Motion detection and speed calculation
- Doppler based Direction of Movement detection

With this platform Infineon also launches for the first time its highly interactive graphical user interface, "RADAR GUI". The Radar GUI software is JAVA based. It provides graphical support for Infineon's radar devices and enables the visualization of raw and processed data from a connected radar device, and also provides other advanced features for data visualization.

The Radar GUI also provides features to record data in several formats for advanced signal processing. Radar GUI supports several recording options. Each option will save corresponding data in a dedicated file as follows:

- **Raw data** – records raw signal data the way they are received from a device. Data is stored in file with .raw extension.
- **Time domain data** – recording extracted time domain data (I & Q signals). Data is stored in file with .tdd extension.
- **Frequency domain data** – recording processed spectrum data. Data is stored in file with .fdd extension.
- **Target data** – recording radar target list data. Data is stored in file with .tdd extension.

The help section integrated inside the RADAR GUI provides a comprehensive overview of all the features.

A Matlab Interface plugin is also available to extract the raw IF data from the radar module via the USB interface to the PC/laptop for further signal processing.

7.1 Software tools to get started

Several software tools need to be preinstalled to get started with the Distance2Go kit.

The Demo board package consists of:

- Distance2Go Demo board: Order Number: SA001703588
- USB cable
- SW GUI to operate kit (Download from Infineon webpage)
- Precompiled C libraries provided (Download from Infineon webpage)
- Source code of FW + basic radar algorithms (Download from Infineon webpage)
- PCB schematic and Gerber files (Download from Infineon webpage)

To gain access to the 24GHz Industrial Radar software portal where you can download Infineon 24GHz software and supporting material, which can only be used with Infineon demo boards, you are required to follow the steps below (must be followed in order).

1. Please complete new user registration: https://www.infineon.com/cms/en/myInfineon/registration/
2. Please email 24GHzSupport@infineon.com requesting access to the restricted collaboration space.
3. Please refer to the Quick Start Guide in the download section for getting started with the demo board.

Sections below provide a list of the general online tools needed and the links to download them. For detailed information on how to get started with the tools, please refer to the supporting documentation available via the online platform inside the software folder.

7.1.1 Tools for firmware development

DAVE

www.infineon.com/dave

SEGGER-J-LINK

This is already part of DAVE installation

7.1.2 Tools for DATA visualization, recording and playback

RADAR GUI

http://download.hitex.de/RadarGUI

7.1.3 Drivers and flashing utilities

XMC4200 Serial Port Drivers

Download from Infineon restricted collaboration space

XMC Flasher

http://www.infineon.com/cms/en/product/microcontroller/32-bit-industrial-microcontroller-based-on-arm-registered-cortex-registered-m/xmc-development-tools-software-tools-and-partner/xmc-programming-tools-from-infineon/channel.html?channel=5546d462557e6e890155a0532c605bfe

Please find all further support material on www.infineon.com/24ghz

8 Authors

Abhiram Chakraborty, Staff Application Engineer of Business Line “Radio Frequency and Sensors”.

Arushi Jain, Application Engineer of Business Line “Radio Frequency and Sensors”.

9 References

[1] Infineon BGT24MTR11–24GHzRadar IC – Datasheet
http://www.infineon.com/dgdl/BGT24MTR11v3.1.pdf?fileId=db3a304339dcf4b10139def491930214

[2] Infineon XMC4200 32-bit ARM CortexTM-M4 Microcontroller – Datasheet
http://www.infineon.com/dgdl/Infineon-XMC4100XMC4200-DS-v0102-en.pdf?fileId=db3a30433afc7e3e013b3cf9b2816573&ack=t

[3] Infineon Application Note – AN305 – “Users Guide to 24GHz Radar Transceiver”

[4] Infineon Application Note –AN341 – “Using BGT24MTR11 in Low Power Applications – 24GHz Radar”

[5] Infineon Application Note – AN380 – “BGT24-RFB2412 – Reference Design Board – User Manual”

[6] Infineon Application Note – AN458 – “Sense2Go2 – 24GHz Radar DEMO kit with XMC4200 32-bit ARM® CortexTM-M4 Microcontroller”

[7] Innosent Application Note - Application Note IV - “Recommendations for the using of radar sensors in general and specifically for low cost devices”

[8] Innosent Application Note – Application Note II – “Detection and Ranging of moving and Stationary Objects by using the FMCW radar principle”

Revision history

Major changes since the last revision

Page or Reference	Description of change
Pg 25	Corrected PCB pin descriptions
Pg 46	Updated links

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